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Stress-testing the Norwegian economy: The effects of the 1.5°C scenario on global energy markets and the Norwegian economy

Developing a baseline scenario by soft-linking three models

TALL SOM FORTELLER

Ådne Cappelen, Solveig Glomsrød, Lars Lindholt,
Knut Einar Rosendahl and Taoyuan Wei

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Preface

In this project we soft-link three models; GRACE, FRISBEE and KVARTS to study the effects on the Norwegian economy of reaching the 1.5°C target. We derive a strategy on how to construct a consistent baseline scenario until 2050 for all three models. This is a collaborative project between Statistics Norway, Norwegian University of Life Sciences and CICERO - Centre for International Climate and Environmental Research. The project is financed by The Research Council of Norway under the ENERGIX programme.

Statistics Norway, 15. January 2021

Linda Nøstbakken

Abstract

In this project we soft-link three models; GRACE, FRISBEE and KVARTS to study the effects on the Norwegian economy of reaching the 1.5°C target of global warming. We develop a strategy on how to construct a consistent baseline scenario until 2050 for all three models. GRACE is a general equilibrium model of the world economy, FRISBEE is a partial equilibrium model of the global energy markets, while KVARTS is a model of the Norwegian economy. For FRISBEE and GRACE, we will align with the regional energy development of the baseline scenario in IEA's World Energy Outlook from 2019, but do not strive for a perfect hit. If the simulated demand of the various energy goods in the different regions is far off targets according to IEA, we will adjust relevant parameters values. Further, due to lack of data we perform various estimations regarding GDP growth rates and CO_2-prices in various regions.

This report depicts a strategy to study the effects on the economy in Norway in a baseline scenario. The most important variables to be implemented from FRISBEE and GRACE in the KVARTS model are oil and gas prices, as well as investment and production profiles of oil and gas. Even if the baseline scenario is the focus in this report, we also describe the flow of variables between the models in the policy scenarios.

Sammendrag

I dette prosjektet kobler vi sammen tre modeller; GRACE, FRISBEE og KVARTS for å studere effektene på norsk økonomi av å nå målet om 1,5 ° C global oppvarming. Vi utarbeider en strategi for hvordan vi kan konstruere et konsistent basisscenario fram til 2050 for alle tre modellene. GRACE er en generell likevektsmodell for den globale økonomien, FRISBEE er en partiell likevekts-modell for de globale energimarkedene, mens KVARTS er en modell for norsk økonomi. For FRISBEE og GRACE vil vi tilpasse oss til den regionale energietterspørselen i basisscenarioet i IEAs World Energy Outlook fra 2019, uten å tilstrebe at utviklingen nødvendigvis skal være identisk lik. Hvis den simulerte etterspørselen av de forskjellige energivarene i de ulike regionene avviker mye fra utviklingen til IEA, kan vi justere relevante parametere. På grunn av mangel på data utfører vi for øvrig estimeringer av vekstrater for BNP og CO_2-priser for flere land/regioner.

Denne rapporten skisserer en strategi for å studere effektene på norsk økonomi i et basisscenario. De viktigste variablene som skal tas fra FRISBEE og GRACE og implementeres i KVARTS er priser og investerings- og produksjonsprofiler for olje og gass. Selv om basisscenarioet er fokus i denne rapporten, beskriver vi også strømmen av variabler mellom modellene i politikk-analyser.

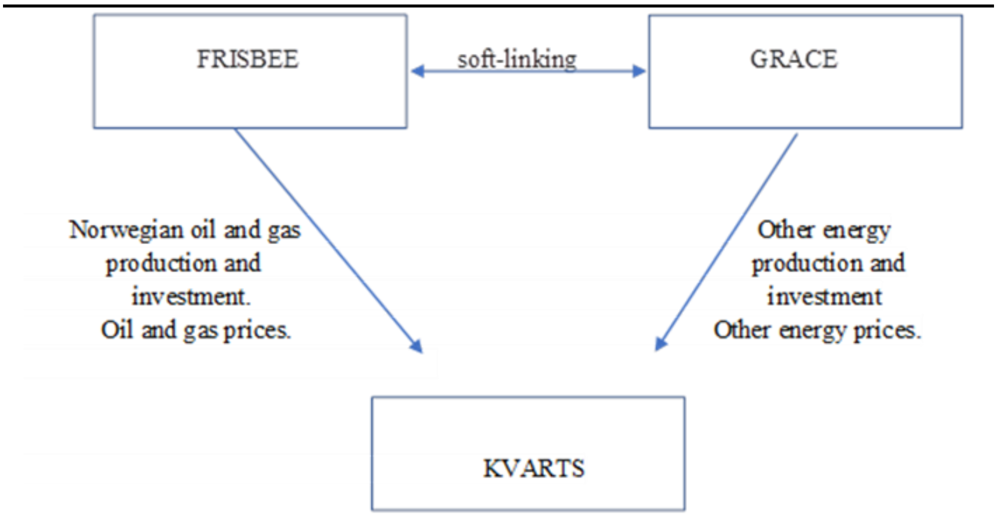
Contents

1. Introduction

In this project we soft-link three models; GRACE, FRISBEE and KVARTS.[1] This document discusses the external settings and key assumptions for all three models until 2050 that secure a consistent modelling tool for the project “Stress-testing the Norwegian economy: The effects of the 1.5°C scenario on global energy markets and the Norwegian economy”. In this document we focus on the baseline scenario which is the starting point for policy analysis.[2]

GRACE is a general equilibrium model of the world economy. FRISBEE is a partial equilibrium model of the global energy markets. Both models cover all 18 regions listed in Section 2. Our baseline scenarios build on the Stated Policy Scenario (STEPS) in IEA (2019). Assumptions on population development, GDP growth rates and CO_2-prices (and to some extent other policy related variables) in each region will be taken from IEA (2019) and included in both models. Due to lack of data we perform various estimations regarding GDP growth rates and CO_2-prices.[3] The Norwegian economy is the focus of KVARTS. For KVARTS the other regions are mainly important when it comes to Norwegian export, which in KVARTS is measured by aggregating the imports from Norway by Norway’s main trading partners. In KVARTS the GDP growth in some of the regions in Section 2 are indicators of foreign demand and world market prices for Norwegian goods, e.g. in Western Europe, United Kingdom, USA, Japan, China. Population in Norway is endogenous because immigration is modelled in KVARTS (by, inter alia, relative income and labour market condition in Norway vs. abroad). In KVARTS the Norwegian GDP growth is also endogenous. Figure 1 shows the flow of *energy data* between the models. In Section 7 we discuss the detailed flows of all relevant data between the models.

Figure 1.1 Flow of energy data between the models in the baseline scenario



[1] GRACE: Global Responses to Anthropogenic Changes in the Environment, FRISBEE: Framework of International Strategic Behavior in Energy and Environment, KVARTS indicates a quarterly model.

[2] Even if the baseline scenario is the focus in this document, we will comment on some features of the models that relates to the policy scenarios.

[3] In policy simulations in GRACE, factor endowment is scaled by the calibrated parameters of factor productivity and real GDP is endogenously determined within the model. Hence, in policy simulations the endogenous GDP growth rates (and CO_2-prices) in GRACE will be implemented in FRISBEE. See Table 7.2 in Section 7.

We will explain later why future Norwegian oil and gas production and prices as well as investment are used as input from FRISBEE into KVARTS. Further, other energy data will be taken from GRACE and included in KVARTS[4]. The models are updated and calibrated to the agreed baseline settings and assumptions. If the simulated demand (or supply) of the various energy goods in the different regions is far off targets in STEPS, we can adjust central parameter values. In the policy scenarios several iterative simulations will be carried out to ensure the models work properly, particularly considering the convergence of key variables shared by GRACE and FRISBEE. In Section 7 there is an overview of which variables that are taken from either of the two models and inserted into KVARTS in both the baseline and the policy scenario. This section also includes a discussion of how to proceed when both GRACE and FRISBEE produces an endogenous variable that is relevant as an input to KVARTS. Further, we explain why it also could be relevant to implement some of the Norwegian data from KVARTS in GRACE and FRISBEE.

[4] This could be electricity, the refined oil sector and an infinitesimal coal industry. In the policy scenarios future Norwegian supply of hydrogen will be input from either GRACE or FRISBEE into KVARTS.

2. Regional resolution

As a starting point, we follow the original regional distribution in FRISBEE excluding Greenland (see Lindholt and Glomsrød, 2018). However, we separate Australia and New Zealand from OECD Pacific (OEP) as one region (ANZ). We also take Japan out from OEP as a single region. The main reason is that ANZ has a large potential for renewable electricity supply in terms of solar and wind power, and possibly for green hydrogen production in addition to hydrogen from fossil energy. Japan is a large economy that is expected to substitute fossil and nuclear energy with renewables and hydrogen, and is already engaged in joint initiatives with Australia on future deliveries.

Further, Brazil is separated as a single region from Latin America (LAM) to highlight Brazil as an important producer of bioenergy, e.g. biofuels to the transport sector. Qatar is treated as a part of OPEC even if it withdrew from the cartel in 2019.

Table 2.1 Regions in GRACE and FRISBEE

NOR: Norway.
UKI: United Kingdom.
WEU (Western Europe): Austria, Belgium, Denmark, Finland, France, Germany, Gibraltar, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, Sweden, Switzerland.
EEU (Eastern Europe): Albania, Bosnia and Herzegovina, Bulgaria, Czech Republic, Croatia, Cyprus, Estonia, Hungary, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, Ukraine, Belarus.
USA: United States of America.
CAN: Canada.
OEP (OECD Pacific): South Korea, Taiwan.
ANZ: Australia, New Zealand.
JPN: Japan.
RUS: Russia.
CAR (Caspian region): Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan.
OPC (OPEC Core): Kuwait, Qatar, Saudi Arabia, United Arab Emirates.
OPR (OPEC Rest): Algeria, Angola, Gabon, Iran, Iraq, Libya, Nigeria, Venezuela.
CHI: People's Republic of China, Hong Kong China.
RAS (Rest of Asia): Bahrain, Bangladesh, Brunei, Cambodia, India, Indonesia, Israel, Jordan, Lebanon, Malaysia, Mongolia, Myanmar/Burma, Nepal, North Korea, Oman, Pakistan, Philippines, Singapore, Sri Lanka, Syria, Thailand, Turkey, Vietnam, Yemen, "" Other Asia ", see “Energy balances of Non-OECD countries, Section 4 Geographical coverage in Part 1: Methodological notes” in IEA (2020a).
AFR (Africa): Benin, Botswana, Cameroon, Congo, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Ghana, Ivory Coast, Kenya, Morocco, Mozambique, Namibia, Senegal, South Africa, Sudan, Tanzania, Togo, Tunisia, Zambia, Zimbabwe, "" Other Africa ", see “Energy balances of Non-OECD countries, Section 4 Geographical coverage in Part 1: Methodological notes” in IEA (2020a).
BRA: Brazil.
LAM (Latin America): Argentina, Bolivia, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, Ecuador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Mexico, "" Other Latin America ", see “Energy balances of Non-OECD countries, Section 4 Geographical coverage in Part 1: Methodological notes” in IEA (2020a).

3. Population

Population growth is a major driver behind economic growth and energy use. In this study, total population by region is taken from The Medium Variant Scenario of UNDP World Population perspective 2019 version (United Nations, 2019). See Table A.1 in Appendix A.

However, population trends are changing and appropriate methods for making population projections are being considered. Besides UN projections there are two other relevant projections available. The IIASA Wittgenstein Centre predicts a faster decline in the total fertility rate (TFR). More specifically they predict a faster TFR decline in Sub-Saharan Africa than UNDP, a result of accounting for educational impact in their qualitative assessment. Recently, more advanced modelling of the fertility rate, i.e. making the TFR endogenous was introduced for providing projections for the Global Burden of Diseases, Injuries and Risk Factors Study (Stevens et al, 2016). The Wittgenstein method is closer to this recent approach, neither of which reflect the UN view on continued population growth during this century.

These lower population perspectives will imply a diminishing workforce and modified growth in GDP and energy demand. However, a perceived shortage of labour and higher wages might cause a shift towards increased capital-energy input in production.

Climate models used in IPCC (Intergovernmental Panel on Climate Change) context have mainly used the IIASA-Wittgenstein projections. The choice of the UN medium variant scenario might thus require a tougher climate policy than under the two other population projections to achieve the Paris target. Hence, we will consider applying alternative population trends than that of UN.

4. GDP development

4.1 GDP growth rates

We checked several sources for data on long-term GDP development of countries and regions. IMF (2019) only provides data to 2024. Hence, we rely on data from OECD and IEA. OECD (2018) has data available for every year to 2060, with a somewhat limited coverage of non-OECD countries. IEA (2019) provides average yearly growth rates for three periods 2000-2018, 2018-2030 and 2030-2040. We emphasize that information on the development in the first period (even if it is the past) is necessary for the passage to the second period and estimation of the first yearly growth rates in this period.

In OECD (2018) we find GDP data for the period 2010-2060 at constant 2010 USD PPP prices for our regions/countries. Hence, we can use these growth rates for the calibration of our model (below). However, when adjusting the GDP growth rates to align with the data in IEA (2019), we face difficulties with smoothening of the GDP trends in OECD (2018) around the IEA periodic shifts in 2030 and 2040. Instead, to obtain a smooth GDP path for the future while aligning with the periodic data in IEA (2019), we introduce the GDP development rate ($D_{r,t}$). This denotes the ratio of GDP at the year t to the GDP of the previous year, for the smoothened GDP path in Eq. (1). We assume that the development rates $D_{r,t}$ of the smoothened GDP (in region r and year t) depend exponentially on the year t, where $D_{r,t}$ equals one plus the growth rate of GDP in year t:

$$D_{r,t} = EXP(a(t-2000)^{0.2} + b(t-2000)^{0.1} + c) \qquad (1)$$

To estimate the parameters a, b, and c, we use the yearly development rates in Eq. (1) to calculate the accumulated GDP growth rate of each of the three periods (2000-2018, 2018-2030 and 2030-2040), which is forced to equal the corresponding accumulated GDP growth rate of that from IEA (2019). At this stage, region r corresponds to the IEA (2019) regional definition, which is different from ours. Hence, we first identify the yearly smoothened GDP development rates of the regions in IEA (2019) and then re-group them to match the regions used in this project as shown in Section 2.

Table 4.1 Average yearly growth rates of GDP by IEA (2019) regions

	Compound average annual growth rate			
	2000-18	2018-30	2030-40	2018-40
North America	2.0%	2.0%	2.1%	2.0%
United States	1.9%	1.9%	2.0%	2.0%
Central and South America	2.6%	2.7%	3.0%	2.9%
Brazil	2.3%	2.5%	3.1%	2.8%
Europe	1.8%	1.7%	1.5%	1.6%
European Union	1.6%	1.6%	1.4%	1.5%
Africa	4.3%	4.2%	4.3%	4.3%
South Africa	2.7%	2.1%	2.9%	2.5%
Middle East	3.9%	2.9%	3.6%	3.2%
Eurasia	4.0%	2.4%	2.3%	2.3%
Russia	3.4%	1.8%	1.9%	1.8%
Asia Pacific	6.0%	5.0%	3.7%	4.4%
China	8.9%	5.2%	3.3%	4.3%
India	7.3%	7.3%	5.2%	6.4%
Japan	0.8%	0.7%	0.7%	0.7%
Southeast Asia	5.2%	4.9%	3.8%	4.4%
World	3.7%	3.6%	3.1%	3.4%

Source: IEA (2019).

The development rates of each region can be calculated for each of the periods 2000-2018, 2018-2030, and 2030-2040 based on the figures in Table 4.1. The estimated development rates from Eq.1 must meet these rates over the three periods, i.e. for each region the product of yearly development rates generates the exogenous development rate determined by the GDP growth rate of IEA (2019) for the corresponding period. We get the following equations:

$$\prod_{t=2000}^{2018} D_{r,t} = \overline{D}_r^{\,2018-2000},\ \prod_{t=2018}^{2030} D_{r,t} = \overline{D}_r^{\,2030-2018},$$
$$\prod_{t=2030}^{2040} D_{r,t} = \overline{D}_r^{\,2040-2030}$$

where the parameters on the right-hand sides are accumulated development rates of GDP from IEA (2019). The parameters a, b, and c can be derived as shown in Table 4.2 by simultaneously solving the three equations above.

Table 4.2 Estimated parameters for Eq. 1 by IEA (2019) regions

	a	b	c
North America	0.078998	-0.198850	0.143722
United States	0.073114	-0.188445	0.139781
Central and South America	0.189765	-0.473361	0.318740
Brazil	0.317191	-0.790879	0.512765
Europe	-0.100367	0.247841	-0.133847
European Union	-0.158115	0.403477	-0.240269
Africa	0.102606	-0.265669	0.212543
South Africa	0.791090	-2.056313	1.351917
Middle East	0.755932	-1.994505	1.341481
Eurasia	0.358983	-1.023316	0.751602
Russia	0.479854	-1.327558	0.935863
Asia Pacific	-0.704797	1.736507	-1.005792
China	-0.414128	0.818020	-0.290886
India	-1.512275	3.856770	-2.372278
Japan	0.080272	-0.215549	0.151088
Southeast Asia	-0.783420	1.978101	-1.190121
World	-0.304889	0.770642	-0.448084

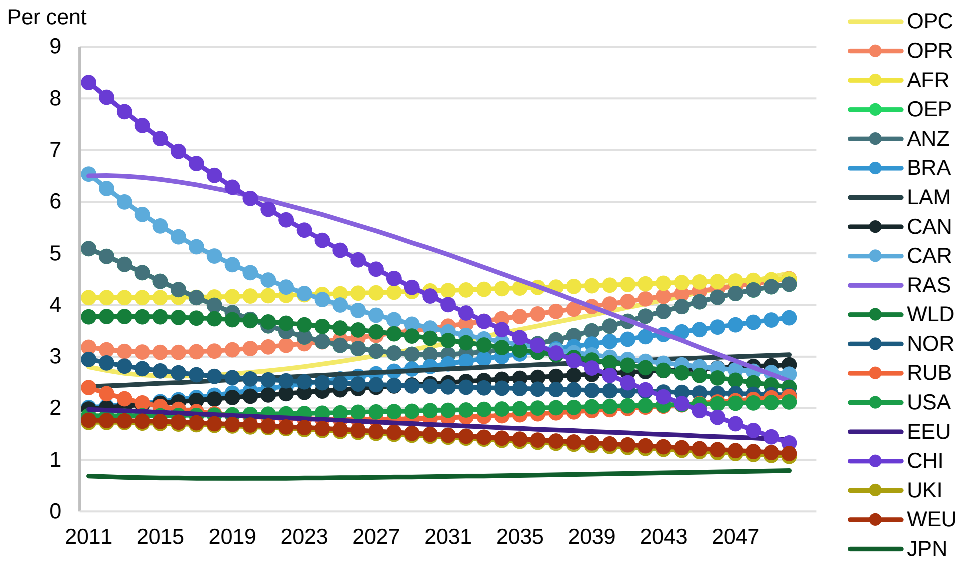
By using the estimated parameters in Eq. (1), we obtain the growth rates of the IEA regions listed in Table 4.1 from 2000 to 2040. We directly obtain growth rates for individual countries including USA, Brazil (BRA), Russia (RUS), China (CHI), India (IND), and Japan (JPN). We apply the regional growth rates for countries belonging to the European Union, Africa, Middle East, and Southeast Asia.

For all other regions we assume that the GDP growth rates follow that of the IEA region they belong to. However, in some cases these IEA regions include sub-regions for which we already know the GDP growth rates. In these cases, for example, USA is included in the IEA region North America. The GDP growth rates of the other countries in North America (i.e. Canada and Mexico) are estimated as the adjusted regional growth rate after the GDP of USA is deducted.

We extract the PPP GDP data of 2018 from the data at country level in IMF (2019), which the IEA growth rates were based on. For all the IEA regions, we assume the GDP of 2018 is the same as that from the IMF data, which enable us to calculate the GDP of all years 2010-2050 by using the estimated growth/development rates from Eq. 1 (and for 2040-2050 we prolong the trends). Then we can deduct sub-regional GDP from its aggregated regions, e.g., the GDP of USA is removed from that of North America. The GDP growth rates for these regions are then re-calculated for the remaining countries in the regions.

The estimated growth rates of GDP are shown in Figure 2 below. The growth rates 2010-2018 may differ from the historical path, which should not be an issue since we focus on long-term development rather than short-term fluctuations.

Figure 4.1 Estimated yearly growth rates of GDP



For a complete set of regional growth rates, see Table B.1 in Appendix B.

4.2 GDP growth per capita

As population development probably will take unusual paths due to low fertility rates and ageing over the next decades, it would be useful to look closer at GDP per capita. China's population will peak at 1.472 billion around 2030 according to United Nations (2019), like what is indicated in the population projections in United Nations (2015, 2017). Is 2050 GDP growth rate per capita unreasonably low for China? As Figure 4.2 shows it approaches a rate of 1.75 per cent, which is above the level in 2050 for only three regions; WEU (1.38 per cent), Japan (1.49 per cent) and UK (0.89 per cent). However, we conclude that due to ageing and low fertility rates the GDP growth rate that comes from the functional form in Eq 1 for China are reasonable. In addition, as Figure 4.4 shows the growth rates per capita are very high for OEP, OPC and ANZ, above all towards the end of the projection period. This could make it relevant to reduce those rates and check the effects on energy demand. This is also the case with Brazil as Figure 4.2 shows.

For a complete set of regional growth rates, see Table B.2 in Appendix B.

Figure 4.2 Estimated yearly growth rates of GDP per capita. Selected regions

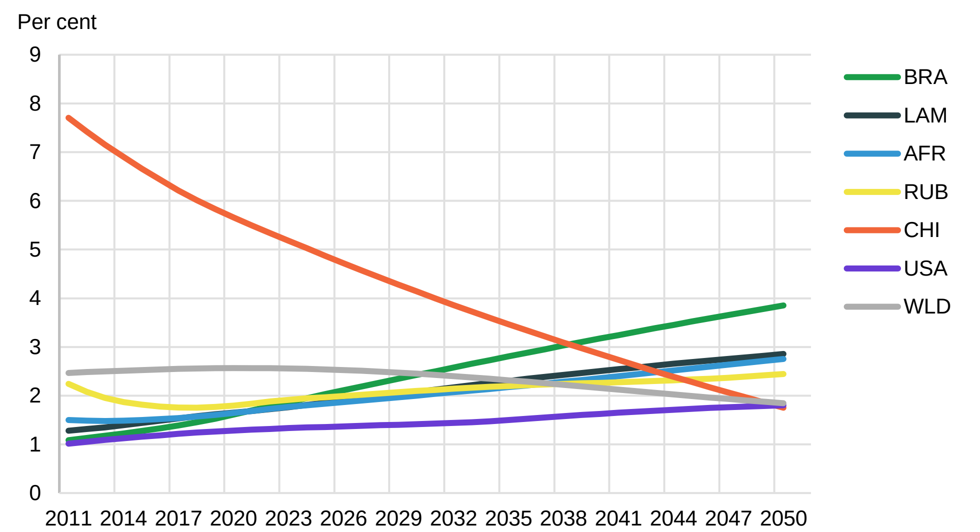


Figure 4.3 Estimated yearly growth rates of GDP per capita. Selected regions

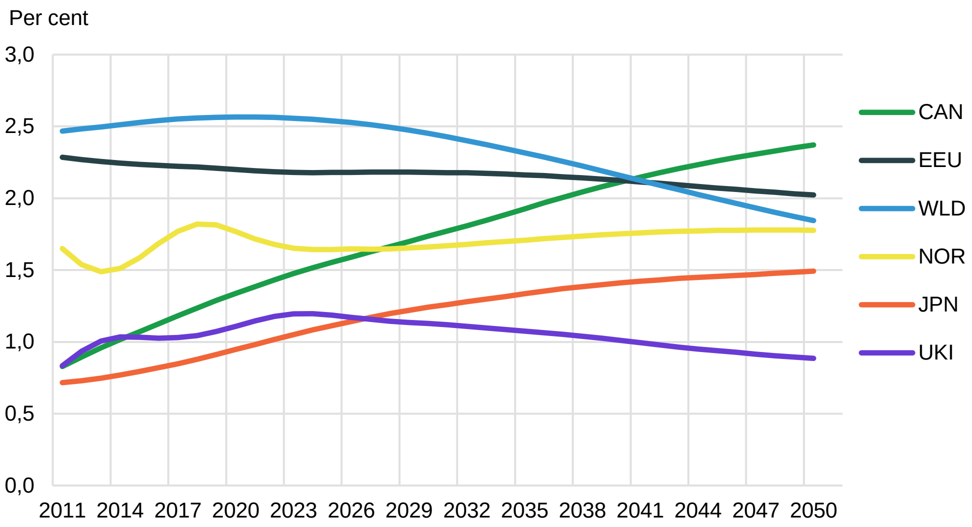
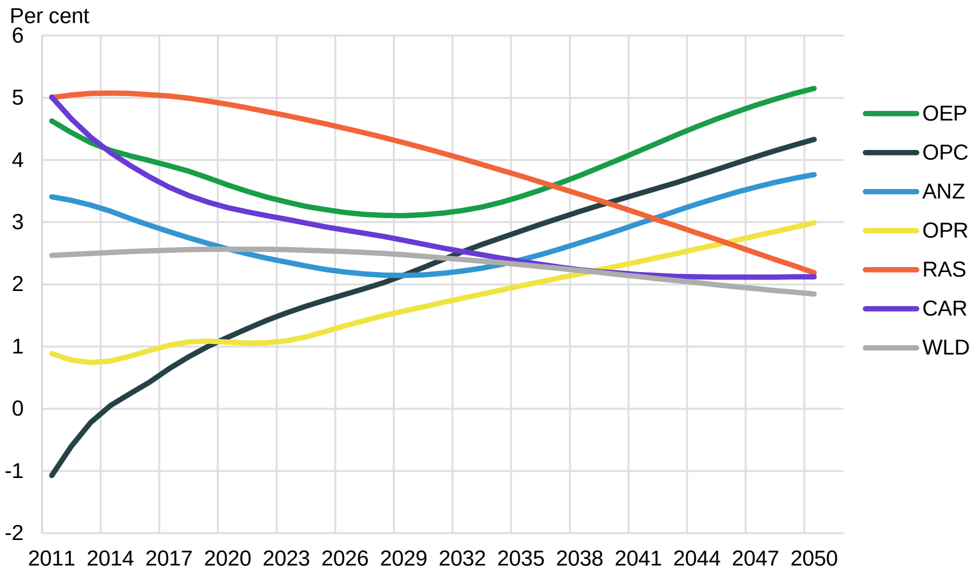


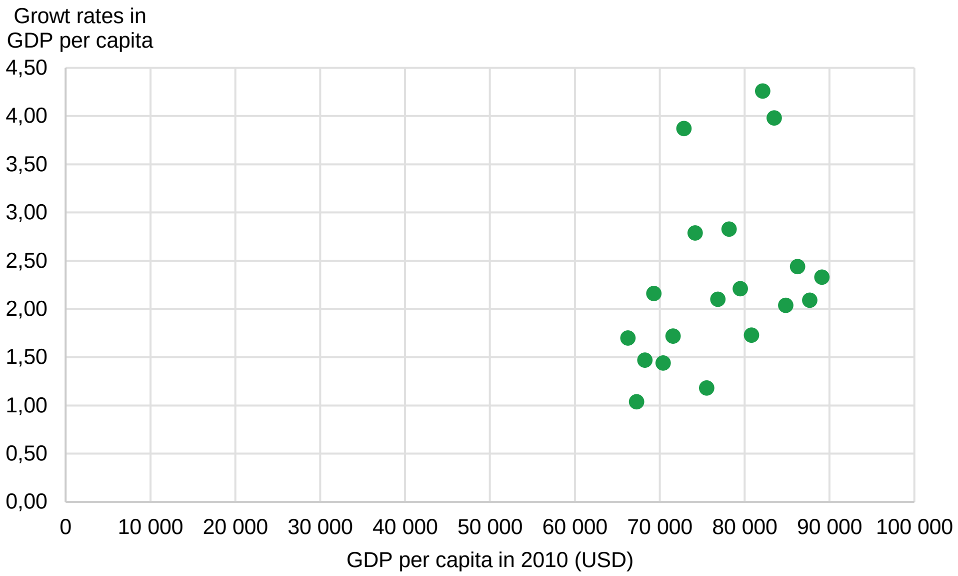
Figure 4.4 Estimated yearly growth rates of GDP per capita. Selected regions



4.3 Are incomes levels converging according to the GDP forecasts?

A well-known hypothesis from neoclassical theory of economic growth is that in the long run there should be a tendency for per capita income levels across countries to converge unless countries are subject to idiosyncratic shocks. Although such absolute convergence is not likely to occur, there should at least be a tendency towards conditional convergence. So, adjusting for possible regional or country specific shocks the higher the initial income level, the lower the growth rate should be. To control for a reasonable set of factors affecting economic growth is not our focus here. Let us instead simply characterize the forecast we have discussed in this report through the lenses of the hypothesis of economic convergence. Figure 4.5 shows a scatter plot of the growth rates in GDP per capita for the various countries/regions in our study on the y-axis and the level of GDP per capita in 2010 in USD (PPPs). If anything, there seems to be a positive and not negative correlation between growth and income levels.

Figure 4.5 Per capita economic growth (in percent) 2010-50 and income levels in USD (PPP) in 2010



This is also born out if we regress the growth rate on the initial income level. However, this regression suffers from possible misspecification due to outliers so standard tests could be misleading. Excluding these observations results in a model with desirable properties that fit the data well. The estimated coefficient for the initial income level is very small (although significantly positive) implying that there still is a positive effect from initial income on economic growth. The outliers are China, South Korea and Taiwan (OEP) and RAS. To conclude, even after adjusting for these anomalies there is no tendency for convergence in income levels over time in this forecast.

5. Demand and supply of energy goods

5.1. Introduction

FRISBEE is a recursive, dynamic partial equilibrium model for the global energy markets. The start-year is 2012 and prices are stated in 2012-USD and exchange rates are held constant over time. The recursive model is solved sequentially year by year. The model covers coal, oil, gas and bio, and further, electricity generation based on either of the fossil fuels or non-fossil feedstock, assisted by a transformation sector. For each energy good global demand equals supply.

GRACE is a multi-sector, multi-region recursive dynamic computable general equilibrium (CGE) model for the global economy. The start-year is 2014 and prices are stated in 2014-USD and exchange rates are held constant over time. Like FRESBEE the GRACE model is solved sequentially year by year. In the model regional economies are divided into 15 production activities including agriculture, forestry, fishery, three manufacturing (iron and steel, non-metallic minerals, other manufacturing), three transport (air, sea, and others), services, and five energy (coal, oil, gas, refined oil and electricity). Electricity generation is based on feedstock of either fossil fuels (coal, oil, and gas) or non-fossil (nuclear, hydro, wind, and others), assisted by a transformation sector. For each good demand equals supply globally.

5.2 Demand

5.2.1 Energy goods

FRISBEE:
Primary energy goods: Crude oil, gas, steam coal, coking coal, lignite, renewables (incl. nuclear), bio.

Secondary energy goods: Stationary oil, transport oil, gas, steam coal, coking coal, lignite, electricity, heat, CHP (Combined cycle heat and power), bio (-product).

Demand for bioproducts in household and industry is exogenous. Volumes of non-fossil fuels as renewables (incl. nuclear) are exogenous to the power sector. We apply the regional volume figures from the baseline scenario (STEPS) in IEA (2019).

GRACE:
Primary energy goods: Crude oil, gas, coal, in an enhanced model version also: hydro, nuclear, renewables.

Secondary energy goods: Refined oil, gas, coal, electricity

5.2.2 Energy sectors

FRISBEE:
Final end-users:
Industry, Households.

Intermediate users:
Power sector, Heat sector, CHP sector

Demands for all secondary energy goods other than bio are log-linear functions of end-user prices and income. In addition, there are autonomous energy efficiency improvement (AEEI). The end-user prices are the sum of producer price, transport, distribution and marketing costs, VAT and a carbon (CO_2) tax.

The per capita income elasticities vary a lot, from negative elasticities for coal in Western Europe to somewhat below one for natural gas in several other regions. The long-run direct price elasticity varies between -0.1 and -0.6 with a weighted average of -0.30 for households and -0.21 for industries for all energy goods. Most cross-price elasticities are relatively low. However, substitution possibilities are markedly higher in the power sector than in manufacturing and households/services.

GRACE
End-users:
Producing sectors: Crude oil, Coal, Refined oil, Electricity, Gas, Agriculture, Forestry, Fisheries, Iron and steel, Non-metallic minerals, Other manufacturing, Air transport, Sea transport, Other transport, Services.

Consuming sectors: Household, Government.

Intermediate users:
Power sector, Producing sectors (also) receives intermediate deliveries.

Demands for energy goods are derived from nested-CES functions of consumers' utility and corresponding functions of optimal output for producers with respect to end-user prices of energy and other goods, and productive resources. AEEI is exogenous and optional for all use of energy and other goods. The end-user prices are CES combinations of prices of domestically produced goods and corresponding imported goods. Prices of imported goods include domestic prices of exporters, international transport and transaction costs simulated by CES functions. Taxes and subsidies including a carbon tax are represented as (base year) shares of relevant prices. In the CES functions, the elasticities are exogenous following previous studies and other parameters are calibrated based on base-year data.

5.2. Supply

FRISBEE has an elaborate modelling of the global oil market and the regional gas markets, while the worldwide markets for coal, electricity and renewables are modelled with less detail. Fossil fuels are traded between regions, whereas electricity is only traded within each region. Coal and oil are traded via a common pool, whereas gas trade takes place bilaterally between the 18 regions depending on transportation costs. The gas and coal markets are assumed to be competitive. The world market price of oil is exogenous as OPEC is expected to satisfy the residual demand, determined as the difference between world demand and Non-OPEC supply at the prevailing oil price. The fixed price assumption implies that demand and Non-OPEC supply are determined independently of each other. FRISBEE depicts the gas market both as global and integrated. A major factor behind this development is the decline in costs of transportation of LNG. Thus, within the gas markets we have perfect competition both upstream and downstream, and the gas price is determined endogenously in regional markets. There is no restriction on investments in transport capacity between regions if it is profitable. New transport infrastructure can be sea transport for LNG and/or pipeline for natural gas. Each year the cheapest transport technology between pair of regions is chosen for given capacity investments. Thus, a region may import both via LNG and pipeline transport, but not from the same region. However, changes in transport costs over time might imply changing transportation methods.

FRISBEE provides elaborate modelling of investments and production, accounting explicitly for discoveries, reserves, field development and production of oil and gas. Oil and gas production generally take place in the 18 regions and 4 field categories depending on location onshore/offshore, depth of offshore fields and size of resources. However, Norway deviates from this classification by having four field categories which are geographical; Barents Sea, Lofoten/Vesterålen/ Senja, Norwegian Sea and North Sea.

For oil and gas FRISBEE distinguishes between three field stages within each field category, i.e. fields in production, undeveloped fields and undiscovered fields. Supply from developed fields in the model is determined so that marginal operating costs equal producer prices net of gross taxes. Operating costs are increasing functions of production but are generally low unless production is close to the fields' production capacity when they increase rapidly. The cost functions are calibrated based on data on production costs in different locations.

Oil and gas companies may invest in new fields and in reserve extensions of developed fields. Investments decisions are driven by expected net present values (NPV), which are calculated for each field category in each region. Expected NPV depends on expected price (the average over last six years), the time lag from investment decision to maximum plateau production, a pre-specified required rate of return (e.g. 10 per cent in real terms), unit operating and capital costs, and net and gross tax rates. Unit capital costs are convex in the short term, and increase when the pool of undeveloped reserves available for new fields declines and when the recovery rate rises in the case of reserve extension. Investments first target the most profitable areas and gradually shift to more remote and costly areas, leading to a geographically spread of the global oil and gas production.

New oil and gas discoveries are modelled in a simpler way than investments in already discovered fields. The amount of discoveries generally depends on expected prices and the amount of undiscovered resources in each region.

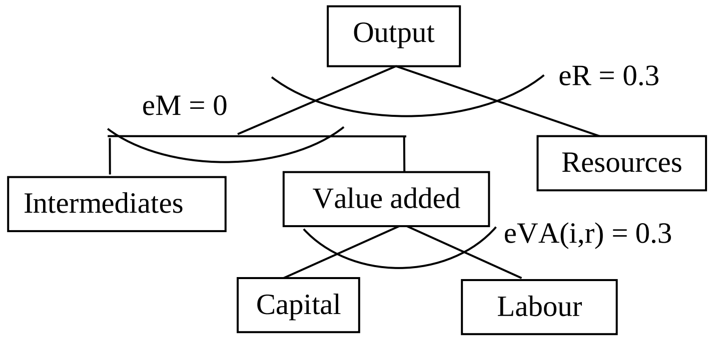
In the model, the global oil and gas industry might allocate up to 50 per cent of the annual cash flow to field investments. The cash flow constraint is generally not binding in our scenarios, i.e. the oil and gas companies invest in all projects that give at least the required rate of return of e.g. 10 per cent.

We also assume perfect competition and endogenous prices in the 18 regional *coal* markets. Regional coal prices are world coal market price plus region specific transportation costs. For coal we apply more simple cost functions than for oil and gas as we do not distinguish between the investment and the production phase. Costs are increasing in accumulated supply, while technological progress leads to lower cost. Regional supply is determined so that marginal operating costs equal producer prices (production capacities are not explicitly modelled). The cost functions are calibrated based on data on production costs in different locations.

Regional electricity production is a function of the electricity price, prices of energy inputs, carbon taxes, fuel efficiency (conversion rates) and generation costs. The regional volume of inputs of renewables (incl. nuclear) is exogenous. We emphasize, as explained above, that the endogenous variables in our model are the regional supply, demand and prices of gas, coal and electricity as well as the demand and supply of oil.

In GRACE nested-CES functions are assumed for production of primary energy – crude oil, coal, and gas as illustrated in Figure 5.1. The parameters starting with small letter "e" indicate the elasticities of substitution (the same for figures illustrating structures of nested functions below). At the top-level, energy output is described by a standard CES function of natural resource and a value-added-intermediate aggregate. The substitution elasticity at the top-level as well as the value share of natural resource determine the price elasticity of supply of fossil fuels. This substitution elasticity is set to 0.3. At the second level, the value-added-intermediate aggregate is depicted by a Leontief function (no substitution) of intermediates (both energy and other intermediate inputs) and the value-added aggregate. The value-added aggregate is a standard CES function of capital and labour. The substitution elasticity between capital and labour determines technological flexibilities in production. The empirical literature typically rejects the hypothesis of a Cobb-Douglas function, where the substitution elasticity between capital and labour equals 1, and shows that the elasticity tends to be less than unity (Arrow et al., 1961). In the core version of the GRACE model, we assume a substitution elasticity of 0.3.

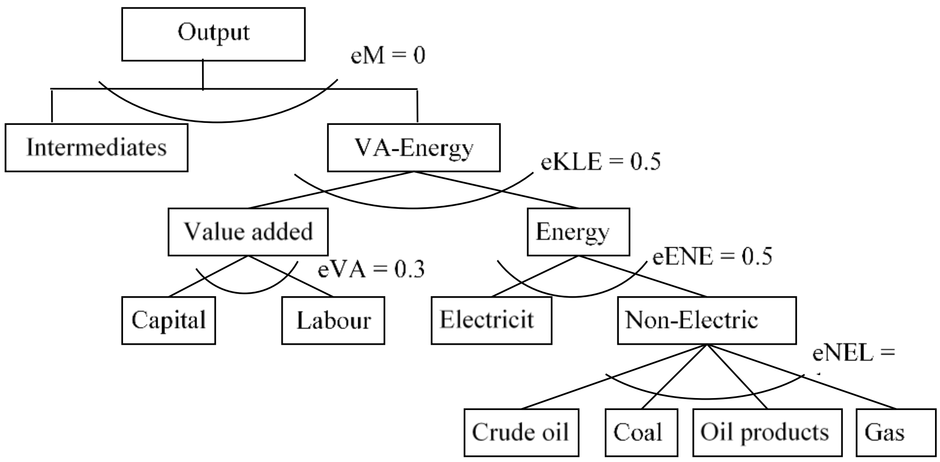
Figure 5.1 Production structure of primary energy goods[1]



[1] Both energy and non-energy inputs are included in the intermediates.
Source: Aaheim et al (2018)

Supply of power is generally assumed to have the same production functions as other goods/services (Figure 5.2). Output is described assuming no substitution (Leontief function) between intermediates and the value-added-energy aggregate. At the second level, the value-added-energy aggregate is a standard CES function of the energy aggregate and the value-added aggregate, with a substitution elasticity of 0.5. The energy aggregate is formed from a CES function of electricity and non-electric energy inputs. The aggregate of non-electric energy inputs is depicted by a Cobb-Douglas function (elasticity of substitution = 1) of coal, crude oil, oil products, and natural gas.

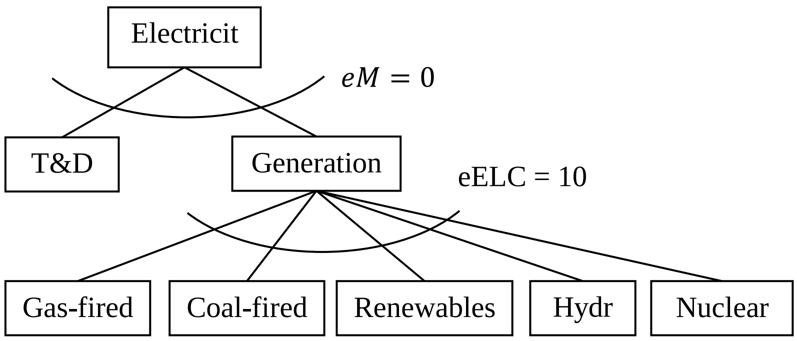
Figure 5.2 Production structure of goods/services other than primary energy[1]



[1] These substitution elasticities are somewhat lower than the elasticities in KVARTS, which have a (long-term) elasticity of 0.85 between labour and capital, and often 0.5 between other inputs. However, we will perform sensitivity analysis by altering the substitution elasticities in our policy scenarios.
Source: Aaheim et al (2018)

In an enhanced version of GRACE focusing on the energy sector, we employ a more elaborated structure for the power generation sector (Figure 5.3). The calibration of the power generation sector is based on the GTAP10-Power database (Chepeliev, 2019), which is an electricity-detailed extension of Version 10 of the GTAP database (Aguiar et al., 2019). The GTAP10-Power database depicts the global economy in 2014 and provides data on 141 regions and 76 commodities. In the GRACE model, the power generation sector is divided into the five sub-sectors gas-fired plants, coal-fired plants, nuclear power, hydropower and renewables.

Figure 5.3 Power generation and transmission and distribution



Source: Aaheim et al (2018)

The power generation sector consists of generation, and transmission and distribution (T&D). Transmission and distribution are represented by a service sector, which is consumed in a fixed proportion relative to power generation, as described by a Leontief function (Peters, 2016b). Following many other CGE-based studies (e.g., Peters, 2016; Sue Wing, 2008; Wing, 2006), we assume imperfect substitutability among technologies to depict market inertias associated with switching from one technology to another. Hence, a stricter climate policy will lead to substitution towards less carbon intensive technologies, without ending up with corner solutions. The choice of elasticity is subject to a compromise between a high elasticity to reflect the homogeneity of the output, and a low elasticity to reflect the incompleteness in switches between technologies.

5.3 Adjusting demand and supply in GRACE and FRISBEE

We will align with the regional energy development of STEPS in IEA (2019), but not strive for a perfect hit. As the functional forms of the two models are different (CES in GRACE; Cobb Douglas in FRISBEE), it is difficult to compare the output directly. However, functional form should not be harmonized as it also can be a strength in the analyses. In this respect it could be useful to do model runs with marginal price or income changes to see to what extent the two models correspond. We emphasize here that substitution elasticities closer to one in GRACE, other things being equal, will make the difference between the two models smaller (as the substitution elasticities between the various energy goods are all equal to one in FRISBEE).

If the simulated demand of the various energy goods in the different regions is far off targets in STEPS, we can adjust e.g. the income elasticities and/or the AEEI or other parameters. Even if demand is most important, we can also adjust the supply function if output of an energy good in a region deviates much from STEPS, e.g. by changing taxes and/or costs. Accuracy is most important for energy goods where regional supply is linked to regional demand, e.g. the gas pipeline demand in Europe (UKI, WEU, EEU) which is important for the residual demand for Norwegian gas supply.

Further, we can deviate from STEPS, but then explain our reason for doing so and refer to other accessible data and information. E.g. we might question whether the IEA crude oil price of $103/barrel ($2018-prices) in 2040 in STEPS is too high for our baseline. However, it is important to come up with other relevant sources of future oil price data that supports our choice.

The corona pandemic and the oil price fall in 2020 will have consequences for both the near-term and to some extent for the long-term development of energy demand, supply, GDP growth etc. (see IEA, 2020b). We start with a long-term perspective as in our baseline scenario from IEA (2019), but we can adjust this with the alternatives/revisions to STEPS in IEA (2020b).

While renewable energy (incl. nuclear) in the power sector is endogenous in GRACE, it is exogenous in FRISBEE. Our goal is to make renewables to the power sector endogenous also in FRISBEE. However, nuclear should still be exogenous and not based on profitability. Further, we will keep bioproducts to industry and households exogenous as it is in the present version of FRISBEE. Bio is not specified in GRACE.

We emphasize that if we can model the same investment regime in GRACE for oil and gas as in FRISBEE, i.e. an exogenous rate of return and expected prices, this can also lead to more consistency between the two models.

6. Policy assumptions in reference scenario

6.1. CO_2-prices in sectors and regions

Below we show the information in IEA (2019) regarding CO_2-prices in STEPS.

Table 6.1 CO_2-prices in selected regions in the Stated Policy Scenario (STEPS) ($2018 per tonne)

Region	Sectors	2030	2040
Canada	Power, industry, aviation, others1	36	39
Chile	Power	12	20
China	Power, industry, aviation	23	36
EU	Power, industry, aviation	33	43
Korea	Power, industry	33	44
South Africa	Power, industry	15	24

[1] In Canada's benchmark/backstop policies, a carbon price is applied to fuel consumed in additional sectors.

National carbon pricing schemes are in place or planned in thirty countries around the world and this is reflected in the projections of STEPS. Once China's national Emissions Trading Scheme is in place from 2020, the share of global emissions covered by carbon prices will rise to around 13 per cent from 7 per cent today (IEA, 2019).

The price of allowances in the European Union Emissions Trading Scheme (EU ETS) is in 2020 just over $20/tonne. Future levels are uncertain, not least because the announced plans of Germany to end its use of coal-fired power plants by 2038 could lead to a large surplus of allowances unless the emissions cap is reduced by a commensurate level. It seems clear that the introduction of the Market Stability Reserve at least will lower the total number of allowances in circulation in phase IV of the EU ETS the next decade.

South Africa introduced a CO_2-tax of $8.5/tonne in June 2019, although there are some tax breaks in the first phase (covering the period to 2022) that lower the effective tax rate to around $0.5-3.5/tonne (IEA, 2019).

There is an interplay between the CO_2-prices assumed and a variety of other policy measures such as vehicle and building efficiency standards, renewable energy targets and support for new technology development. Further details of targets of renewables and CO_2-emissions follow in Section 6.2.

IEA (2019) has no more data available for CO_2-prices than those in Table 6.1. First, we assume linear developments based on this regional data in 2030 and 2040. Further, we must make assumptions about the prices in other countries/regions. See Figure 6.1 and 6.2 for estimated CO_2-prices for all countries/regions based on the discussion below.

We assume that the development of CO_2-prices is the same for WEU, NOR, UKI and EEU, and equal to EU on the assumption that the European continent becomes one common market.

Chile has 9.7 per cent of emission in LAM in 2018. Lacking information on CO_2-prices in other countries, we downscale the CO_2-price in Chile in Table 6.1 accordingly for LAM. Thus, the price in 2030 for LAM is (0.097x12=) $1.164 per tonne.

South Africa has 38 per cent of emissions in Africa in 2018. We downscale the CO_2-price in South Africa accordingly for AFR.

Let the CO_2-price in Korea be the CO_2-price in OEP (Korea and Taiwan).

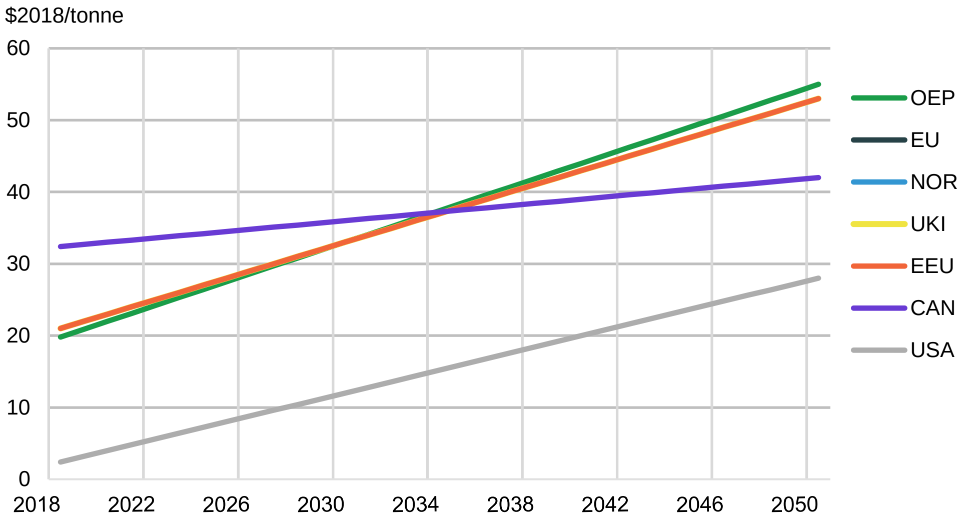
Let USA have the CO_2-price of Chile as they have the lowest prices in Table 6.1. USA have some CO_2-prices and climate policy measures in certain states, so the CO_2-price for the whole USA is certainly higher than zero. Due to lack of information we choose the CO_2-price level of Chile.

New Zealand has 15.8 per cent of the combined emissions of Australia and New Zealand in 2018. We downscale the CO_2-price forecast in New Zealand (see Synapse, 2015) accordingly for ANZ.

We let the CO_2-price in RUS, CAR, OPC and OPR be zero over the whole baseline period.

The target Brazil has for GHG emissions in STEPS is that they shall be 37 per cent lower in 2025 than in 2005 (see Section 6.2). Simulations with GRACE show that to reach such a level of CO_2-emissions, the CO_2-price must be 60 per cent of the price in China (these simulations contain other measures to reach the target, as e.g. energy efficiency, that may deviate from the measures in STEPS). Due to lack of other information, we let the CO_2-price for Brazil be 60 per cent of the level in China.

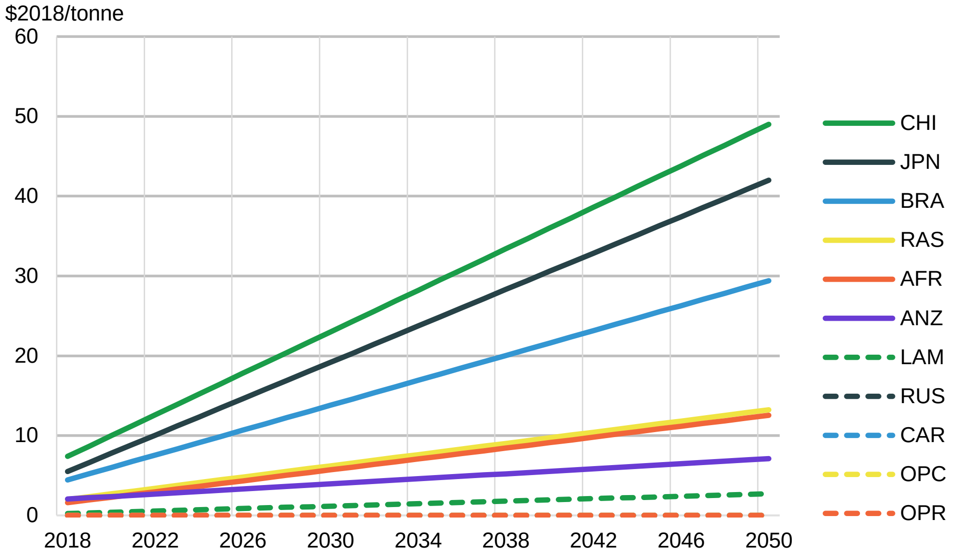
Figure 6.1 Estimated CO_2-prices in various selected countries/regions ($2018 per tonne). EU=NOR=UKI=EE



The targets Japan has for GHG emissions in STEPS is that they shall be 26 per cent lower in 2030 than in 2013 (see Section 6.2). According to International Carbon Action Partnership (2020) the current price of CO_2 per tonne is $5.5 (2019-prices). Due to its ambitious climate target, we let the price of Japan reach that of Canada in 2050.

The targets of India (part of RAS) in STEPS is to reduce GHG emission intensity by 33-35 per cent below 2005-level in 2030 (see Section 6,2.). Targets for India in STEPS are not far from that of Brazil. India has around 45 per cent of total RAS emissions (see USA Today, 2019). Hence, we let the CO_2-price of RAS be 45 per cent of the price in Brazil.

Figure 6.2 Estimated CO_2-prices in various selected countries/regions ($2018 per tonne). RUS=CAR=OPC=OPR=0



For a complete set of regional CO_2-prices, see Table C.1 in Appendix C.

We use the following strategy for introducing CO_2-prices in our models:

In FRISBEE we have two end users: Households, Industries and three Intermediate users: Power, Heat, CHP. We simply apply the same CO_2-prices for Industry, Power (= Heat, CHP) and Households.[5]

End users in GRACE are Agriculture, Forestry, Fisheries, Crude oil, Coal, Refined oil, Electricity, Gas, Iron and steel, Non-metallic minerals, Other manufacturing, Air transport, Sea transport, Other transport, Services, Households, Government. We impose CO_2-prices in Electricity, Iron and steel, Non-metallic minerals, Other manufacturing, Air transport, Households and Government.

CO_2-prices for Norway are also implemented in KVARTS. They are imposed on fuels which is used both in the household sector and as intermediates in the producing sectors.

6.2. Other policies

The policy actions other than explicit CO_2-prices assumed to be taken by governments are a key variable in STEPS and an important reason for the differences in outcomes. An overview of the policies and measures that are considered in IEA (2019) is listed below. We have focused on targets towards renewables and GHG (greenhouse gases)[6]. In the latter section we discuss CO_2-prices. Pricing of CO_2-emissions is by emissions trading systems or taxes (see Table 6.1 above).

6.2.1. Targets for GHG emissions and renewables

European Union

Nationally Determined Contributions (NDC) targets and 2030 Climate and Energy Framework:

-Reduce GHG emissions at least 40 per cent below 1990 levels.

[5] IEA refers to CO_2-taxes only in power, industry and aviation. Due to lack of information we apply the same taxes for households in each region. These are partly gasoline/diesel-taxes, which typically are higher than CO_2-taxes in industry and power.

[6] GRACE and FRISBEE only cover CO_2.

-Increase share of renewables to at least 32 per cent.

-Emissions Trading System (ETS) reducing GHG emissions by 43 per cent below the 2005 level in 2030.

-Increase the share of renewables in heating and cooling by 1 per cent per year to 2030.

Japan
NDC targets:
-Economy-wide target of reducing GHG emissions by 26 per cent below year 2013 levels in year 2030; sector-specific targets.

China
NDC GHG targets:
-Achieve peak CO_2-emissions around 2030, with best efforts to peak early; lower CO_2-emissions per unit of GDP 60-65 per cent below 2005 levels by 2030.

NDC energy target:
-Increase the share of non-fossil fuels in primary energy consumption to 20 per cent by 2030.

13th Five-Year Plan targets for 2020:
-Carbon emissions per unit of GDP limited to 18 per cent below 2015 levels.

India
NDC GHG target:
-Reduce emissions intensity of GDP 33-35 per cent below 2005 levels by 2030.

NDC energy target:
-Achieve about 40 per cent cumulative installed capacity from non-fossil fuel sources by 2030.

Brazil
NDC GHG economy-wide targets:
-Reduce GHG emissions 37 per cent below 2005 levels by 2025.

NDC energy goals for 2030:
-Increase share of sustainable biofuels to around 18 per cent of TPED (total primary energy demand).
-Increase renewables to 45 per cent of TPED.
-Increase non-hydro renewables to 28-30 per cent of TPED and 23 per cent of power supply.

United States
No clear targets towards GHG or renewables at a federal level

From IEA (2019) we have data for CO_2-emissions for all regions. We also have data on future regional volumes of renewables (see Section 4 on how we can regroup the regions in IEA to the regions in our project). A possible strategy to implement climate policies for renewables and emissions in the baseline scenario is:

1) Apply the estimated CO_2-prices in all 18 countries/regions we derive in Section 6.1.
2) If the simulated demand for renewables in the different regions is far off targets in STEPS, we can adjust central parameters. For FRISBEE we can

adjust the exogenous volume of renewables or adjust parameters in the forthcoming demand functions (as e.g. power demand elasticities). In GRACE, the easiest option is adjusting relative prices by a “shadow” tax/subsidy or changes in consumption efficiency parameters.

3) We check the development of CO_2 (GHG)-emissions in the baseline scenarios in each region in IEA (2019). However, as our figures on both regional demand of fossil fuels (see Section 5.4) and renewables shall be more or less in accordance with IEA (see latter paragraph above), the model simulated regional emissions shall not be far off targets in STEPS.

6.2.2. Targets for the power sector

Below we show targets for the power sector in STEPS in various countries/regions. We disregard targets of buildings and the transport sector.

Canada
Complete phase out of traditional coal-fired power in line with the Pan-Canadian Framework on Clean Growth and Climate Change.

European Union
Coal phase out in a subset of member states, notably in Finland, France, Germany, Italy, the Netherlands and United Kingdom.

Korea
Third Master Energy Plan calls for 35-40 per cent renewables by 2040.

Japan
Non-fossil fuels to supply 44 per cent of power generation by 2030, corresponding to carbon intensity of 370 g CO_2/kWh.

China
13th Five-Year Plan targets for 2020:
-58 GW nuclear, 380 GW hydro, at least 210 GW wind and at least 110 GW solar.
-Coal limited to 1 100 GW, by delaying 150 GW of new builds and retiring 20 GW of existing plants.

India
Strengthened measures such as competitive bidding to increase the use of renewables towards the national target of 175 GW of non-hydro renewables capacity by 2022 (100 GW solar, 75 GW non-solar) and 450 GW non-hydro renewables capacity target by 2050.

Chile
Coal phase out by 2030.

We apply the following strategy for reaching the targets for renewables and emissions from the power sector:
Check if the various goals for the power sector are reached in the baseline. If not adjust parameters that affect the demand for the various inputs from the power sector.

7. Flow of variables between the models

Before we turn to the policy scenarios, we study the effects on the economy in Norway in the baseline scenario. The most important variables to be transferred from FRISBEE and GRACE into the KVARTS model are oil and gas prices, as well as the Norwegian investment and production profiles of oil and gas. How should we proceed when both GRACE and FRISBEE produces an endogenous variable that shall be inserted into KVARTS? FRISBEE has a more detailed modelling of oil and gas. Hence, oil and gas production and investment of Norway should preferably be taken from FRISBEE. The same should be valid for oil and gas prices. The output of these variables from GRACE should nevertheless be checked. When it comes to prices, production and investment of other energy goods it seems better to apply the output of GRACE (because FRISBEE has a simpler modelling of other energy sources). This could be electricity, the refined oil sector and a very small coal industry. See Table 7.1 for which variables are implemented from either GRACE or FRISBEE to KVARTS in the baseline scenario.

It *could* be fruitful to introduce the Norwegian population growth from KVARTS in the other two models, even if Norway is not important with respect to these variables in a global setting. The same reasoning is valid for applying GDP growth in Norway from GRACE/KVARTS into FRISBEE. Further, this is also the case with the labour supply of Norway from KVARTS to GRACE (not relevant for FRISBEE). The reason is that if we have a Norwegian instead of a global focus, it could be desirable to have a consistent modelling between the three models regarding population, GDP-growth and labour supply.

Table 7.1 Flow of variables between the models in the baseline scenario

Variables/parameters	FRISBEE	GRACE	KVARTS
Population of Norway	Exogenous	Exogenous	Endogenous
Labour supply of Norway	Not applicable	Exogenous	Endogenous
Population of other regions	Exogenous	Exogenous	Exogenous
GDP of Norway	Exogenous	Endogenous after calibration	Endogenous
GDP of other regions	Exogenous	Endogenous after calibration	Exogenous
CO_2-prices	Exogenous	Endogenous by setting emission target	Exogenous
Renewable targets	Exogenous	Endogenous after calibration	Not applicable
Emission target	Not applicable	Exogenous	Not applicable
Oil and gas production of Norway	Endogenous	Endogenous .	From FRISBEE
Oil prices	Exogenous	Endogenous after calibration	From FRISBEE
Gas prices	Endogenous	Endogenous	From FRISBEE
Oil and gas investment	Endogenous	Endogenous	From FRISBEE
Other energy prices	Endogenous (at present renewables are exogenous)	Endogenous	From GRACE
Other energy production in Norway	Endogenous	Endogenous	From GRACE
Other energy investments in Norway	Endogenous	Endogenous	From GRACE
Investments of non-energy goods in Norway	Not applicable	Endogenous	Endogenous
Import and export from Norway	Endogenous (only energy)	Endogenous	Endogenous
Government consumption in Norway	Not applicable	Endogenous as fixed share of national income	Endogenous

Even if the baseline scenario is the focus in this report, we present an overview of the flow of variables between the models in the policy scenario in Table 7.2. Clearly, GRACE now produces various endogenous variables that can be used by the other two models. We comment specifically on the oil price, which is a central variable in this project where the effects on the Norwegian economy is in focus. In the policy scenario the oil price is (still) exogenous in FRISBEE, while oil prices are endogenous in GRACE (relative to a numeraire). As FRISBEE generates more plausible oil output, we can introduce certain constraints in GRACE, so it is more like FRISBEE. If so, GRACE will generate relative oil prices that can be used by FRISBEE.

Table 7.2 Flow of variables between the models in the policy scenarios

Variables/parameters	FRISBEE	GRACE	KVARTS
Population of Norway	Exogenous	Exogenous	Endogenous
Labour supply of Norway	Not applicable	Exogenous	Endogenous
Population of other regions	Exogenous	Exogenous	Exogenous
GDP of Norway	Exogenous	Endogenous	Endogenous
GDP of other regions	From GRACE	Endogenous	From GRACE
CO_2-prices	From GRACE	Endogenous by setting emission target	From GRACE
Renewable targets	From GRACE	Endogenous	Not applicable
Emission target	Not applicable	Exogenous	Not applicable
Oil and gas production of Norway	Endogenous	Endogenous .	From FRISBEE
Oil prices	From GRACE	Endogenous	From GRACE
Gas prices	Endogenous	Endogenous	From FRISBEE
Oil and gas investment	Endogenous	Endogenous	From FRISBEE
Other energy prices	Endogenous (at present renewables are exogenous)	Endogenous	From GRACE
Other energy production in Norway	Endogenous	Endogenous	From GRACE
Other energy investments in Norway	Endogenous	Endogenous	From GRACE
Investments of non-energy goods in Norway	Not applicable	Endogenous	Endogenous
Import and export from Norway	Endogenous (only energy)	Endogenous	Endogenous
Government consumption in Norway	Not applicable	Endogenous as fixed share of national income	Endogenous

8. Summary

In this project we soft-link three models; GRACE, FRISBEE and KVARTS to study the effects on the Norwegian economy of reaching the 1.5°C target. We derive a strategy on how to construct a consistent baseline scenario until 2050 for all three models. GRACE is a general equilibrium model of the world economy, FRISBEE is a partial equilibrium model of the global energy markets, while KVARTS is a model of the Norwegian economy. The most relevant flow of variables in the baseline scenario is from either FRISBEE or GRACE into KVARTS. The same assumptions on population development, GDP growth rates and CO_2-prices (and to some extent other policy related variables) in each region will be implemented in both FRISBEE and GRACE. For these two global models we will align with the regional energy development of the baseline scenario (STEPS) in IEA (2019), but do not strive for a perfect hit. Due to lack of data we perform various estimations regarding GDP growth rates and CO_2-prices.

If the simulated demand for the various energy goods in the different regions is far off targets according to STEPS, we can adjust e.g. the income elasticities, the AEEI or other relevant parameters. Even if demand is most important, we can also adjust the supply function if output of an energy good in a region deviates much from STEPS, e.g. by changing taxes and/or costs. Accuracy is most important for energy goods where regional supply is linked to regional demand, e.g. the gas pipeline demand in Europe, which is important for the residual demand for Norwegian gas.

This report depicts a strategy to study the effects on the economy in Norway in the baseline scenario. The most important variables to be implemented from FRISBEE and GRACE in the KVARTS model are oil and gas prices, as well as investment and production profiles of oil and gas. We discuss to what extent oil, gas and other variables should be taken from either of the two models. Further, we emphasize that for some analyses it might be relevant to take some Norwegian (endogenous) data from KVARTS and insert into GRACE and FRISBEE. In addition, even if the baseline scenario is the focus in this report, we also describe the flow of variables between the models in the policy scenarios.

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Appendix A

Table A 1 Total population aggregated from The Medium Variant Scenario of UNDP World Population perspective 2019 version. 1000 persons

	NOR	UKI	WEU	EEU	USA	CAN	OEP	ANZ	JPN
2010	4886	63460	341394	183792	309011	34148	72733	26525	128542
2011	4948	64022	342554	183233	311584	34539	73055	26957	128499
2012	5014	64525	343629	182682	314044	34922	73408	27372	128424
2013	5079	64984	344648	182132	316401	35297	73767	27773	128314
2014	5142	65423	345644	181580	318673	35664	74100	28164	128169
2015	5200	65860	346639	181019	320878	36027	74381	28547	127985
2016	5251	66298	347651	180445	323016	36383	74602	28922	127763
2017	5296	66727	348663	179856	325085	36732	74771	29287	127503
2018	5338	67142	349618	179253	327096	37075	74898	29641	127202
2019	5379	67530	350434	178638	329065	37411	74999	29986	126860
2020	5421	67886	351058	178013	331003	37742	75086	30322	126476
2021	5466	68207	351468	177377	332915	38068	75160	30649	126051
2022	5511	68498	351688	176728	334805	38388	75219	30967	125585
2023	5558	68766	351768	176062	336679	38704	75262	31278	125081
2024	5605	69022	351780	175374	338543	39017	75290	31584	124544
2025	5651	69274	351776	174660	340400	39327	75305	31886	123976
2026	5697	69524	351773	173920	342252	39634	75305	32185	123379
2027	5742	69772	351760	173154	344101	39939	75291	32482	122755
2028	5787	70016	351733	172364	345948	40241	75264	32775	122107
2029	5832	70255	351681	171551	347795	40539	75221	33065	121441
2030	5876	70485	351597	170719	349642	40834	75163	33350	120758
2031	5919	70709	351484	169868	351490	41125	75090	33633	120063
2032	5961	70927	351348	168998	353335	41411	74999	33912	119355
2033	6003	71140	351186	168112	355163	41693	74889	34187	118637
2034	6044	71347	350994	167214	356953	41970	74755	34459	117907
2035	6084	71549	350771	166305	358691	42239	74593	34726	117166
2036	6123	71745	350515	165387	360372	42501	74404	34988	116416
2037	6161	71936	350225	164461	361998	42756	74187	35247	115657
2038	6199	72123	349899	163529	363570	43005	73942	35502	114893
2039	6235	72306	349533	162592	365094	43248	73672	35755	114125
2040	6271	72487	349124	161653	366572	43486	73377	36005	113356
2041	6307	72665	348673	160711	368006	43720	73057	36254	112587
2042	6342	72841	348178	159769	369397	43948	72713	36501	111818
2043	6376	73014	347638	158825	370746	44172	72345	36746	111052
2044	6409	73183	347050	157881	372060	44393	71956	36990	110288
2045	6442	73346	346415	156937	373343	44611	71549	37232	109529
2046	6475	73505	345731	155993	374598	44827	71122	37473	108775
2047	6507	73659	345001	155049	375828	45040	70679	37712	108026
2048	6538	73807	344226	154104	377037	45252	70217	37950	107281
2049	6570	73948	343408	153158	378233	45461	69739	38187	106541
2050	6600	74082	342550	152210	379419	45669	69243	38422	105804
2051	6631	74208	341654	151259	380599	45876	68731	38655	105071
2052	6661	74327	340722	150307	381776	46083	68204	38887	104340
2053	6691	74438	339759	149350	382955	46289	67664	39116	103610
2054	6720	74543	338766	148389	384140	46496	67113	39345	102875
2055	6749	74642	337749	147421	385335	46705	66553	39571	102135
2056	6778	74734	336709	146447	386542	46915	65985	39795	101387
2057	6807	74822	335652	145468	387763	47127	65410	40018	100633
2058	6836	74904	334584	144481	388995	47341	64831	40240	99872
2059	6864	74984	333511	143489	390240	47559	64249	40459	99102
2060	6892	75060	332441	142491	391495	47779	63669	40677	98326
2061	6920	75135	331376	141488	392760	48003	63090	40894	97542
2062	6949	75209	330320	140481	394033	48231	62514	41109	96752
2063	6977	75281	329279	139470	395313	48460	61941	41324	95957
2064	7005	75354	328258	138458	396595	48692	61372	41537	95161
2065	7033	75428	327261	137445	397876	48925	60807	41749	94366
2066	7061	75504	326292	136434	399155	49159	60247	41960	93574
2067	7090	75581	325353	135424	400429	49393	59692	42171	92785
2068	7118	75659	324443	134420	401693	49628	59143	42381	92003
2069	7146	75737	323562	133423	402943	49863	58598	42590	91231

	NOR	UKI	WEU	EEU	USA	CAN	OEP	ANZ	JPN
2070	7175	75815	322711	132436	404174	50096	58059	42798	90472
2071	7203	75893	321890	131460	405385	50328	57525	43005	89727
2072	7232	75970	321100	130497	406573	50558	56996	43212	88997
2073	7260	76046	320339	129548	407738	50787	56473	43417	88286
2074	7288	76122	319607	128616	408878	51015	55957	43622	87595
2075	7316	76195	318902	127703	409993	51240	55447	43825	86927
2076	7344	76266	318223	126809	411082	51465	54945	44028	86283
2077	7371	76335	317571	125935	412145	51688	54450	44229	85664
2078	7398	76403	316945	125083	413184	51909	53963	44429	85066
2079	7425	76469	316342	124251	414200	52129	53485	44629	84487
2080	7452	76535	315762	123442	415197	52348	53017	44828	83925
2081	7478	76599	315204	122655	416176	52567	52558	45026	83378
2082	7503	76663	314667	121891	417137	52784	52108	45223	82847
2083	7529	76727	314150	121147	418082	53002	51669	45421	82331
2084	7554	76792	313653	120424	419015	53219	51240	45619	81828
2085	7579	76859	313175	119720	419937	53436	50821	45817	81338
2086	7603	76927	312716	119034	420851	53654	50413	46017	80860
2087	7628	76997	312273	118366	421758	53873	50015	46218	80393
2088	7653	77069	311846	117714	422661	54093	49627	46419	79936
2089	7677	77144	311433	117076	423564	54315	49249	46622	79488
2090	7702	77220	311034	116451	424470	54540	48880	46826	79047
2091	7726	77299	310646	115837	425381	54767	48520	47031	78613
2092	7751	77379	310268	115232	426297	54998	48169	47238	78186
2093	7776	77461	309901	114637	427220	55232	47829	47445	77765
2094	7801	77545	309543	114049	428148	55469	47500	47652	77349
2095	7826	77630	309192	113468	429082	55709	47184	47860	76939
2096	7851	77715	308848	112892	430022	55952	46880	48067	76534
2097	7876	77801	308509	112320	430968	56198	46589	48274	76134
2098	7902	77886	308174	111750	431921	56446	46312	48479	75739
2099	7927	77971	307842	111180	432883	56698	46049	48683	75347
2100	7953	78053	307511	110608	433854	56953	45801	48885	74959

Tabell A.1 Cont

	RUB	CAR	OPC	OPR	CHI	RAS	AFR	BRA	LAM
2010	143479	78814	40820	370990	1375777	2553727	1039304	195714	591352
2011	143703	79961	42418	379427	1383504	2590171	1066410	197515	597995
2012	143994	81178	43841	388271	1391253	2626200	1094343	199287	604599
2013	144325	82448	45113	397370	1398972	2661830	1123045	201036	611144
2014	144665	83746	46281	406505	1406589	2697096	1152434	202764	617596
2015	144985	85052	47382	415526	1414034	2732023	1182439	204472	623934
2016	145275	86361	48416	424363	1421293	2766589	1213041	206163	630145
2017	145530	87666	49369	433074	1428328	2800772	1244222	207834	636233
2018	145734	88956	50253	441797	1435020	2834591	1275921	209469	642217
2019	145872	90214	51078	450733	1441220	2868078	1308064	211050	648121
2020	145934	91431	51856	460023	1446821	2901241	1340598	212559	653962
2021	145912	92598	52591	469711	1451769	2934083	1373486	213993	659744
2022	145806	93716	53287	479733	1456076	2966561	1406729	215354	665451
2023	145629	94787	53951	489991	1459781	2998589	1440353	216642	671063
2024	145399	95819	54591	500336	1462958	3030054	1474410	217863	676552
2025	145133	96818	55212	510660	1465664	3060867	1508935	219021	681896
2026	144834	97784	55819	520936	1467903	3090986	1543926	220115	687086
2027	144503	98716	56413	531191	1469666	3120404	1579365	221143	692122
2028	144142	99624	56989	541444	1470978	3149113	1615247	222107	696997
2029	143756	100517	57539	551731	1471867	3177115	1651569	223009	701709
2030	143348	101403	58057	562082	1472359	3204408	1688321	223852	706254
2031	142921	102286	58544	572493	1472469	3230979	1725498	224636	710627
2032	142480	103164	59001	582954	1472207	3256802	1763089	225362	714825
2033	142032	104042	59432	593476	1471575	3281859	1801081	226029	718851
2034	141581	104920	59839	604072	1470573	3306130	1839455	226636	722707
2035	141133	105800	60227	614754	1469202	3329600	1878194	227184	726395
2036	140691	106683	60595	625522	1467469	3352260	1917281	227672	729917
2037	140257	107568	60945	636375	1465387	3374108	1956702	228103	733272
2038	139835	108451	61277	647310	1462968	3395150	1996434	228477	736460
2039	139425	109326	61596	658320	1460225	3415395	2036458	228795	739485
2040	139031	110190	61903	669399	1457172	3434854	2076750	229059	742348
2041	138654	111040	62199	680544	1453817	3453525	2117291	229269	745050
2042	138294	111876	62485	691753	1450167	3471410	2158062	229427	747592
2043	137949	112692	62758	703015	1446219	3488518	2199032	229534	749976
2044	137618	113486	63016	714317	1441970	3504860	2240172	229593	752207
2045	137299	114251	63257	725651	1437418	3520448	2281453	229605	754287
2046	136990	114988	63479	737007	1432571	3535283	2322852	229570	756217
2047	136691	115696	63685	748381	1427440	3549366	2364351	229491	757998
2048	136400	116374	63877	759768	1422036	3562700	2405933	229366	759629
2049	136112	117024	64058	771163	1416367	3575285	2447580	229196	761107
2050	135824	117648	64232	782562	1410446	3587122	2489275	228980	762432
2051	135536	118245	64400	793959	1404285	3598214	2531002	228720	763605
2052	135246	118815	64560	805346	1397898	3608562	2572740	228415	764625
2053	134952	119361	64712	816713	1391303	3618153	2614472	228067	765496
2054	134653	119885	64853	828046	1384519	3626973	2656178	227674	766218
2055	134346	120390	64982	839334	1377568	3635014	2697840	227237	766792
2056	134030	120877	65098	850571	1370463	3642273	2739442	226756	767221
2057	133707	121345	65204	861754	1363222	3648756	2780967	226233	767504
2058	133376	121798	65298	872881	1355870	3654470	2822404	225668	767643
2059	133037	122235	65380	883952	1348435	3659422	2863745	225060	767640
2060	132692	122658	65452	894968	1340943	3663621	2904977	224412	767495
2061	132341	123067	65512	905925	1333408	3667074	2946088	223723	767210
2062	131984	123464	65562	916821	1325844	3669790	2987058	222994	766789
2063	131625	123846	65603	927653	1318266	3671773	3027869	222227	766231
2064	131266	124214	65635	938419	1310693	3673029	3068500	221422	765540
2065	130910	124565	65661	949117	1303138	3673565	3108931	220580	764717
2066	130557	124902	65680	959745	1295613	3673394	3149145	219702	763765
2067	130209	125223	65693	970302	1288123	3672534	3189127	218789	762687
2068	129870	125528	65703	980789	1280668	3671009	3228861	217843	761486
2069	129542	125818	65710	991209	1273241	3668849	3268333	216866	760163
2070	129229	126092	65716	1001563	1265840	3666079	3307528	215858	758723
2071	128933	126350	65721	1011849	1258468	3662718	3346428	214823	757169
2072	128654	126593	65727	1022064	1251130	3658787	3385017	213761	755504
2073	128393	126821	65733	1032207	1243824	3654315	3423279	212674	753731
2074	128152	127035	65739	1042277	1236542	3649332	3461197	211564	751854
2075	127933	127236	65747	1052271	1229284	3643867	3498757	210433	749876
2076	127735	127424	65756	1062186	1222051	3637943	3535942	209282	747801
2077	127558	127600	65766	1072020	1214849	3631578	3572737	208113	745633
2078	127403	127764	65777	1081765	1207686	3624788	3609122	206930	743377
2079	127267	127919	65789	1091415	1200572	3617588	3645073	205735	741038
2080	127150	128064	65800	1100962	1193514	3609993	3680571	204531	738620
2081	127051	128201	65811	1110402	1186518	3602018	3715601	203319	736128
2082	126969	128329	65822	1119733	1179590	3593682	3750151	202103	733566
2083	126902	128449	65832	1128951	1172744	3585006	3784211	200882	730938

	RUB	CAR	OPC	OPR	CHI	RAS	AFR	BRA	LAM
2084	126848	128560	65840	1138054	1165998	3576013	3817772	199660	728248
2085	126805	128662	65845	1147042	1159365	3566721	3850826	198436	725502
2086	126772	128756	65848	1155909	1152848	3557148	3883362	197212	722703
2087	126747	128841	65848	1164652	1146447	3547304	3915371	195991	719855
2088	126726	128915	65845	1173266	1140171	3537193	3946842	194772	716962
2089	126708	128978	65837	1181745	1134027	3526816	3977767	193557	714028
2090	126688	129027	65826	1190086	1128019	3516177	4008138	192347	711056
2091	126665	129063	65811	1198282	1122142	3505283	4037947	191143	708050
2092	126637	129085	65792	1206331	1116387	3494147	4067188	189946	705014
2093	126604	129091	65768	1214229	1110739	3482784	4095856	188756	701950
2094	126565	129083	65740	1221973	1105182	3471209	4123946	187575	698862
2095	126520	129059	65708	1229559	1099697	3459434	4151453	186402	695753
2096	126466	129019	65672	1236982	1094264	3447471	4178373	185239	692626
2097	126403	128961	65633	1244239	1088862	3435326	4204704	184085	689484
2098	126330	128884	65589	1251325	1083473	3423005	4230441	182941	686329
2099	126244	128787	65542	1258235	1078073	3410510	4255583	181807	683165
2100	126143	128668	65492	1264964	1072641	3397838	4280127	180683	679993

Appendix B

Table B 1 Regional GDP growth rates (%).

	USA	LAM	BRA	AFR	RUB	CHI	JPN	CAN	NOR
2010	1.859157	2.404764	2.001884	4.154417	2.540096	8.609765	0.697455	1.957472	3.034104
2011	1.854893	2.417900	2.016132	4.146775	2.399790	8.309425	0.682318	1.984765	2.950035
2012	1.852880	2.432280	2.037586	4.142483	2.283324	8.021951	0.670454	2.012619	2.879322
2013	1.852656	2.447592	2.064633	4.140860	2.186222	7.746120	0.661232	2.040746	2.819219
2014	1.853873	2.463610	2.096075	4.141391	2.105088	7.480878	0.654176	2.068942	2.767674
2015	1.856264	2.480161	2.131005	4.143683	2.037290	7.225307	0.648917	2.097062	2.723123
2016	1.859623	2.497114	2.168724	4.147429	1.980757	6.978608	0.645164	2.124997	2.684348
2017	1.863784	2.514364	2.208686	4.152387	1.933827	6.740081	0.642688	2.152672	2.650389
2018	1.868617	2.531831	2.250459	4.158360	1.895156	6.509107	0.641300	2.180027	2.620473
2019	1.874015	2.549447	2.293695	4.165190	1.863639	6.285139	0.640849	2.207023	2.593973
2020	1.879890	2.567159	2.338116	4.172748	1.838361	6.067690	0.641207	2.233627	2.570373
2021	1.886171	2.584920	2.383493	4.180926	1.818555	5.856325	0.642269	2.259819	2.549246
2022	1.892797	2.602694	2.429639	4.189635	1.803575	5.650652	0.643947	2.285583	2.530233
2023	1.899718	2.620448	2.476397	4.198800	1.792870	5.450320	0.646165	2.310909	2.513030
2024	1.906891	2.638154	2.523640	4.208356	1.785971	5.255009	0.648859	2.335792	2.497379
2025	1.914281	2.655788	2.571259	4.218249	1.782471	5.064429	0.651974	2.360228	2.483060
2026	1.921855	2.673331	2.619163	4.228434	1.782019	4.878317	0.655463	2.384216	2.469880
2027	1.929589	2.690763	2.667276	4.238871	1.784310	4.696432	0.659284	2.407758	2.457675
2028	1.937458	2.708068	2.715533	4.249524	1.789074	4.518552	0.663402	2.430857	2.446300
2029	1.945444	2.725232	2.763879	4.260365	1.796078	4.344476	0.667785	2.453516	2.435629
2030	1.953529	2.742242	2.812268	4.271366	1.805112	4.174015	0.672405	2.475742	2.425552
2031	1.961697	2.759085	2.860658	4.282507	1.815992	4.006997	0.677239	2.497539	2.415972
2032	1.969937	2.775750	2.909017	4.293766	1.828555	3.843261	0.682264	2.518914	2.406801
2033	1.978236	2.792228	2.957314	4.305126	1.842654	3.682661	0.687461	2.539873	2.397964
2034	1.986584	2.808509	3.005526	4.316572	1.858159	3.525056	0.692814	2.560424	2.389393
2035	1.994973	2.824584	3.053629	4.328091	1.874950	3.370320	0.698306	2.580575	2.381029
2036	2.003394	2.840444	3.101606	4.339670	1.892924	3.218332	0.703925	2.600332	2.372818
2037	2.011840	2.856081	3.149441	4.351298	1.911983	3.068980	0.709657	2.619703	2.364713
2038	2.020306	2.871488	3.197122	4.362966	1.932041	2.922159	0.715493	2.638696	2.356672
2039	2.028786	2.886658	3.244635	4.374666	1.953020	2.777771	0.721421	2.657320	2.348658
2040	2.037275	2.901582	3.291971	4.386390	1.974849	2.635722	0.727433	2.675581	2.340637
2041	2.045769	2.916253	3.339123	4.398132	1.997462	2.495927	0.733521	2.693488	2.332581
2042	2.054264	2.930664	3.386083	4.409884	2.020800	2.358304	0.739677	2.711048	2.324464
2043	2.062755	2.944809	3.432846	4.421643	2.044808	2.222774	0.745894	2.728269	2.316262
2044	2.071242	2.958679	3.479405	4.433403	2.069437	2.089265	0.752167	2.745159	2.307957
2045	2.079719	2.972268	3.525759	4.445160	2.094641	1.957708	0.758490	2.761726	2.299529
2046	2.088186	2.985567	3.571902	4.456909	2.120378	1.828038	0.764857	2.777977	2.290965
2047	2.096640	2.998570	3.617833	4.468648	2.146610	1.700193	0.771263	2.793918	2.282251
2048	2.105079	3.011269	3.663549	4.480373	2.173300	1.574114	0.777706	2.809559	2.273375
2049	2.113501	3.023655	3.709050	4.492082	2.200416	1.449746	0.784180	2.824905	2.264329
2050	2.121904	3.035720	3.754333	4.503772	2.227928	1.327034	0.790682	2.839965	2.255105

Tabell B.1 Cont.

	UKI	WEU	EEU	OEP	ANZ	CAR	OPC	OPR	RAS
2010	1.723107	1.764830	1.984970	5.214094	5.214094	6.839651	2.903209	3.246232	6.472395
2011	1.727353	1.766751	1.974089	5.089621	5.089621	6.539570	2.801444	3.179943	6.499350
2012	1.727127	1.764685	1.961864	4.944402	4.944402	6.259249	2.727755	3.133901	6.504861
2013	1.723369	1.759482	1.948635	4.787423	4.787423	5.998286	2.676568	3.104035	6.493112
2014	1.716784	1.751775	1.934652	4.624995	4.624995	5.755835	2.643687	3.087257	6.467148
2015	1.707909	1.742050	1.920101	4.461613	4.461613	5.530825	2.625890	3.081179	6.429239
2016	1.697163	1.730682	1.905123	4.300537	4.300537	5.322092	2.620658	3.083926	6.381114
2017	1.684877	1.717967	1.889826	4.144171	4.144171	5.128454	2.625991	3.094000	6.324119
2018	1.671313	1.704141	1.874295	3.994334	3.994334	4.948762	2.640279	3.110194	6.259323
2019	1.656686	1.689395	1.858597	3.852435	3.852435	4.781922	2.662211	3.131522	6.187592
2020	1.641168	1.673884	1.842784	3.719598	3.719598	4.626911	2.690711	3.157175	6.109644
2021	1.624905	1.657736	1.826898	3.596746	3.596746	4.482777	2.724882	3.186480	6.026081
2022	1.608014	1.641057	1.810973	3.484657	3.484657	4.348647	2.763975	3.218878	5.937422
2023	1.590595	1.623935	1.795035	3.383999	3.383999	4.223715	2.807358	3.253896	5.844118
2024	1.572732	1.606445	1.779108	3.295352	3.295352	4.107249	2.854495	3.291140	5.746569
2025	1.554496	1.588648	1.763209	3.219216	3.219216	3.998575	2.904925	3.330272	5.645135
2026	1.535946	1.570599	1.747351	3.156014	3.156014	3.897082	2.958255	3.371007	5.540142
2027	1.517135	1.552342	1.731547	3.106088	3.106088	3.802210	3.014144	3.413102	5.431891
2028	1.498107	1.533916	1.715807	3.069685	3.069685	3.713448	3.072295	3.456351	5.320659
2029	1.478899	1.515356	1.700137	3.046945	3.046945	3.630329	3.132450	3.500575	5.206706
2030	1.459545	1.496689	1.684543	3.037889	3.037889	3.552429	3.194384	3.545624	5.090274
2031	1.440073	1.477941	1.669031	3.042396	3.042396	3.479356	3.257899	3.591369	4.971595
2032	1.420508	1.459132	1.653605	3.060191	3.060191	3.410754	3.322818	3.637699	4.850883
2033	1.400871	1.440283	1.638267	3.090830	3.090830	3.346293	3.388987	3.684521	4.728346
2034	1.381182	1.421410	1.623019	3.133688	3.133688	3.285674	3.456268	3.731755	4.604180
2035	1.361457	1.402526	1.607863	3.187953	3.187953	3.228619	3.524539	3.779333	4.478570
2036	1.341710	1.383645	1.592800	3.252623	3.252623	3.174874	3.593692	3.827200	4.351697
2037	1.321954	1.364777	1.577832	3.326513	3.326513	3.124202	3.663627	3.875308	4.223728
2038	1.302201	1.345932	1.562957	3.408269	3.408269	3.076386	3.734258	3.923618	4.094829
2039	1.282460	1.327118	1.548176	3.496380	3.496380	3.031225	3.805506	3.972099	3.965154
2040	1.262740	1.308344	1.533490	3.589217	3.589217	2.988532	3.877300	4.020726	3.834854
2041	1.243049	1.289614	1.518896	3.685054	3.685054	2.948133	3.949576	4.069478	3.704070
2042	1.223393	1.270936	1.504396	3.782111	3.782111	2.909868	4.022276	4.118342	3.572942
2043	1.203779	1.252314	1.489988	3.878597	3.878597	2.873585	4.095349	4.167306	3.441601
2044	1.184211	1.233752	1.475671	3.972745	3.972745	2.839144	4.168747	4.216365	3.310175
2045	1.164694	1.215255	1.461445	4.062858	4.062858	2.806414	4.242426	4.265515	3.178786
2046	1.145232	1.196826	1.447307	4.147347	4.147347	2.775271	4.316348	4.314757	3.047552
2047	1.125829	1.178468	1.433258	4.224759	4.224759	2.745600	4.390478	4.364094	2.916588
2048	1.106488	1.160183	1.419296	4.293810	4.293810	2.717291	4.464782	4.413530	2.786005
2049	1.087212	1.141973	1.405419	4.353400	4.353400	2.690242	4.539231	4.463072	2.655909
2050	1.068003	1.123841	1.391628	4.402628	4.402628	2.664356	4.613799	4.512730	2.526405

Table B 2 Regional GDP growth rates per capita (%)

	NOR	UKI	WEU	EEU	USA	CAN	OEP	ANZ	JPN	RUB	CAR	OPC
2011	1.65	0.83	1.42	2.29	1.01	0.83	4.63	3.41	0.72	2.24	5.01	-1.07
2012	1.54	0.93	1.45	2.27	1.06	0.89	4.44	3.35	0.73	2.08	4.67	-0.61
2013	1.49	1.01	1.46	2.26	1.09	0.96	4.28	3.27	0.75	1.95	4.37	-0.22
2014	1.51	1.03	1.46	2.24	1.13	1.02	4.16	3.17	0.77	1.87	4.12	0.05
2015	1.59	1.03	1.45	2.24	1.16	1.07	4.07	3.06	0.79	1.81	3.91	0.24
2016	1.68	1.03	1.43	2.23	1.19	1.12	3.99	2.95	0.82	1.78	3.73	0.43
2017	1.77	1.03	1.42	2.22	1.22	1.18	3.91	2.85	0.85	1.76	3.56	0.64
2018	1.82	1.04	1.43	2.22	1.24	1.24	3.82	2.75	0.88	1.75	3.43	0.84
2019	1.81	1.07	1.45	2.21	1.26	1.29	3.71	2.66	0.91	1.77	3.32	1.00
2020	1.77	1.11	1.49	2.20	1.28	1.34	3.60	2.57	0.95	1.79	3.24	1.15
2021	1.72	1.15	1.54	2.19	1.30	1.38	3.49	2.49	0.98	1.83	3.17	1.29
2022	1.68	1.18	1.58	2.18	1.32	1.43	3.40	2.42	1.02	1.88	3.10	1.42
2023	1.65	1.19	1.60	2.18	1.33	1.48	3.32	2.36	1.05	1.92	3.05	1.54
2024	1.64	1.20	1.60	2.18	1.35	1.52	3.26	2.29	1.08	1.95	2.99	1.65
2025	1.64	1.19	1.59	2.18	1.36	1.55	3.20	2.24	1.11	1.97	2.93	1.75
2026	1.65	1.17	1.57	2.18	1.37	1.59	3.16	2.20	1.14	1.99	2.87	1.84
2027	1.65	1.16	1.56	2.18	1.38	1.63	3.12	2.17	1.17	2.02	2.82	1.93
2028	1.65	1.14	1.54	2.18	1.39	1.66	3.11	2.15	1.20	2.04	2.77	2.03
2029	1.65	1.13	1.53	2.18	1.40	1.70	3.10	2.14	1.22	2.07	2.71	2.15
2030	1.66	1.13	1.52	2.18	1.42	1.74	3.12	2.15	1.24	2.10	2.65	2.27
2031	1.67	1.12	1.51	2.18	1.43	1.77	3.14	2.18	1.26	2.12	2.59	2.40
2032	1.68	1.11	1.50	2.18	1.44	1.81	3.18	2.21	1.28	2.14	2.53	2.52
2033	1.69	1.10	1.49	2.17	1.45	1.85	3.24	2.26	1.30	2.16	2.47	2.64
2034	1.70	1.09	1.48	2.17	1.48	1.89	3.32	2.32	1.32	2.18	2.42	2.75
2035	1.71	1.08	1.47	2.16	1.50	1.93	3.41	2.39	1.33	2.20	2.37	2.86
2036	1.72	1.06	1.46	2.16	1.53	1.97	3.52	2.48	1.35	2.21	2.32	2.96
2037	1.73	1.05	1.45	2.15	1.55	2.01	3.63	2.57	1.37	2.23	2.28	3.07
2038	1.74	1.04	1.44	2.14	1.58	2.04	3.75	2.66	1.39	2.24	2.24	3.17
2039	1.75	1.03	1.43	2.13	1.60	2.08	3.88	2.77	1.40	2.25	2.21	3.27
2040	1.75	1.01	1.43	2.12	1.63	2.11	4.01	2.87	1.41	2.26	2.18	3.36
2041	1.76	0.99	1.42	2.11	1.65	2.15	4.14	2.97	1.42	2.27	2.16	3.45
2042	1.76	0.98	1.41	2.10	1.67	2.18	4.27	3.08	1.43	2.29	2.14	3.55
2043	1.77	0.96	1.41	2.09	1.69	2.21	4.41	3.19	1.44	2.30	2.13	3.64
2044	1.77	0.95	1.41	2.08	1.71	2.23	4.53	3.29	1.45	2.31	2.12	3.74
2045	1.78	0.94	1.40	2.07	1.73	2.26	4.66	3.39	1.46	2.33	2.12	3.85
2046	1.78	0.93	1.40	2.06	1.75	2.28	4.77	3.48	1.46	2.35	2.12	3.95
2047	1.78	0.91	1.39	2.05	1.76	2.31	4.88	3.56	1.47	2.37	2.12	4.05
2048	1.78	0.90	1.39	2.04	1.78	2.33	4.98	3.64	1.48	2.39	2.12	4.15
2049	1.78	0.89	1.38	2.03	1.79	2.35	5.07	3.71	1.48	2.42	2.12	4.24
2050	1.78	0.89	1.38	2.02	1.80	2.37	5.15	3.76	1.49	2.44	2.12	4.33

Tabell B.2 Cont.

	OPR	CHI	RAS	AFR	BRA	LAM
2011	0.89	7.70	5.00	1.50	1.09	1.28
2012	0.78	7.42	5.04	1.48	1.13	1.31
2013	0.74	7.15	5.07	1.48	1.18	1.35
2014	0.77	6.90	5.08	1.49	1.23	1.39
2015	0.84	6.66	5.07	1.50	1.28	1.44
2016	0.94	6.43	5.05	1.52	1.33	1.49
2017	1.02	6.21	5.03	1.54	1.39	1.53
2018	1.07	6.01	4.99	1.57	1.45	1.58
2019	1.09	5.83	4.95	1.61	1.53	1.62
2020	1.07	5.66	4.90	1.64	1.61	1.65
2021	1.06	5.50	4.84	1.69	1.70	1.69
2022	1.06	5.34	4.78	1.73	1.78	1.72
2023	1.09	5.18	4.71	1.77	1.87	1.76
2024	1.16	5.03	4.65	1.80	1.95	1.81
2025	1.24	4.87	4.58	1.83	2.03	1.85
2026	1.33	4.72	4.51	1.87	2.11	1.90
2027	1.42	4.57	4.44	1.90	2.19	1.94
2028	1.50	4.43	4.36	1.93	2.27	1.99
2029	1.57	4.28	4.28	1.97	2.35	2.04
2030	1.64	4.14	4.20	2.00	2.43	2.08
2031	1.71	4.00	4.11	2.04	2.50	2.13
2032	1.78	3.86	4.02	2.07	2.58	2.17
2033	1.85	3.73	3.93	2.10	2.65	2.22
2034	1.91	3.60	3.84	2.14	2.73	2.26
2035	1.98	3.47	3.74	2.18	2.81	2.30
2036	2.04	3.34	3.65	2.21	2.88	2.34
2037	2.10	3.22	3.55	2.25	2.95	2.39
2038	2.17	3.09	3.45	2.29	3.03	2.43
2039	2.23	2.97	3.35	2.32	3.10	2.47
2040	2.30	2.85	3.25	2.36	3.17	2.50
2041	2.37	2.73	3.14	2.40	3.24	2.54
2042	2.43	2.62	3.04	2.44	3.31	2.58
2043	2.50	2.50	2.93	2.48	3.38	2.62
2044	2.57	2.39	2.83	2.52	3.45	2.65
2045	2.64	2.28	2.72	2.56	3.52	2.69
2046	2.71	2.17	2.62	2.60	3.59	2.72
2047	2.78	2.07	2.51	2.63	3.65	2.76
2048	2.85	1.96	2.40	2.67	3.72	2.79
2049	2.92	1.86	2.29	2.71	3.79	2.82
2050	2.99	1.75	2.19	2.75	3.85	2.86

Appendix C

Table C 1 Regional CO_2-prices. $2018

	NOR	UKI	EU	EEU	USA	CAN	OEP	ANZ	JPN	RUS	CAR	OPC
2018	21	21	21	21	2	32	20	2	6	0	0	0
2019	22	22	22	22	3	33	21	2	7	0	0	0
2020	23	23	23	23	4	33	22	2	8	0	0	0
2021	24	24	24	24	5	33	23	3	9	0	0	0
2022	25	25	25	25	6	34	24	3	10	0	0	0
2023	26	26	26	26	6	34	25	3	11	0	0	0
2024	27	27	27	27	7	34	26	3	12	0	0	0
2025	28	28	28	28	8	35	28	3	13	0	0	0
2026	29	29	29	29	9	35	29	3	15	0	0	0
2027	30	30	30	30	10	35	30	3	16	0	0	0
2028	31	31	31	31	10	35	31	4	17	0	0	0
2029	32	32	32	32	11	36	32	4	18	0	0	0
2030	33	33	33	33	12	36	33	4	19	0	0	0
2031	34	34	34	34	13	36	34	4	20	0	0	0
2032	35	35	35	35	14	37	35	4	21	0	0	0
2033	36	36	36	36	14	37	36	4	23	0	0	0
2034	37	37	37	37	15	37	37	5	24	0	0	0
2035	38	38	38	38	16	38	39	5	25	0	0	0
2036	39	39	39	39	17	38	40	5	26	0	0	0
2037	40	40	40	40	18	38	41	5	27	0	0	0
2038	41	41	41	41	18	38	42	5	28	0	0	0
2039	42	42	42	42	19	39	43	5	29	0	0	0
2040	43	43	43	43	20	39	44	6	31	0	0	0
2041	44	44	44	44	21	39	45	6	32	0	0	0
2042	45	45	45	45	22	40	46	6	33	0	0	0
2043	46	46	46	46	22	40	47	6	34	0	0	0
2044	47	47	47	47	23	40	48	6	35	0	0	0
2045	48	48	48	48	24	41	50	6	36	0	0	0
2046	49	49	49	49	25	41	51	6	37	0	0	0
2047	50	50	50	50	26	41	52	7	39	0	0	0
2048	51	51	51	51	26	41	53	7	40	0	0	0
2049	52	52	52	52	27	42	54	7	41	0	0	0
2050	53	53	53	53	28	42	55	7	42	0	0	0

Table C.1. Cont.

	OPR	CHI	RAS	AFR	BRA	LAM
2018	0	7	2	2	4	0
2019	0	9	2	2	5	0
2020	0	10	3	2	6	0
2021	0	11	3	3	7	0
2022	0	13	3	3	8	1
2023	0	14	4	3	8	1
2024	0	15	4	4	9	1
2025	0	17	4	4	10	1
2026	0	18	5	4	11	1
2027	0	19	5	5	11	1
2028	0	20	6	5	12	1
2029	0	22	6	5	13	1
2030	0	23	6	6	14	1
2031	0	24	7	6	15	1
2032	0	26	7	6	15	1
2033	0	27	7	7	16	1
2034	0	28	8	7	17	1
2035	0	30	8	7	18	2
2036	0	31	8	8	18	2
2037	0	32	9	8	19	2
2038	0	33	9	8	20	2
2039	0	35	9	9	21	2
2040	0	36	10	9	22	2
2041	0	37	10	9	22	2
2042	0	39	10	10	23	2
2043	0	40	11	10	24	2
2044	0	41	11	10	25	2
2045	0	43	11	11	26	2
2046	0	44	12	11	26	2
2047	0	45	12	12	27	2
2048	0	46	13	12	28	3
2049	0	48	13	12	29	3
2050	0	49	13	13	29	3

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