Dynamic (GTAP) model and baseline for energy and environment issues

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Abstract

Dynamic CGE models are widely used in research on long-term energy and climate policies. Whilst a range of models exist, their emphasis is clearly on energy products. For a more general evaluation of energy and climate related policies on e.g. evolution of production structures, in combination with changes in macroeconomic characteristics, like aging population and increased labour skill levels, the GTAP data and Dynamic Model provide an appealing tool. However, the latter does not take into account the special characteristics of the energy products and the policy instruments such as emission trade.

This paper presents a modified version of the dynamic GTAP-model and a long-run baseline, constructed particularly for analysis of energy and environment issues. The model incorporates CO2 emissions accounting and trading, as well as substitution between alternative forms of energy following the principles introduced in the GTAP-E model. The baseline includes, apart from the standard macroeconomic projections, assessments of new technologies enhancing energy use and production. Some example simulations illustrating the effects of alternative growth assumptions using the model and baseline are also given.

The additional model features are implemented in a manner that allows flexibility with regard to sector and region aggregation and the sets of energy commodities. Whilst the basic principle builds primarily on the solutions incorporated in the GTAP-E model, changes are made to the defining of additional sets and, more importantly, to the treatment of emissions trade participation. This is required to enable gradual extension of trading area and flexible simulation of alternative policy options. An attempt is also made to extend the energy commodities to alternative sources, especially biofuel, as GTAP data provides an excellent framework for analysing the topical issues related to energy and food supply.

The macroeconomic variables for a long-run baseline, reaching up to year 2050, are compiled from various international sources and calibrated. These variables include projections for population, skilled and unskilled labour force, and total factor productivity. In addition, with help of energy technology systems models, estimates are produced for increase in energy efficiency and for technological change enhancing energy production.

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1. Associated files and tools

gdyne.tab

This is the main tablo file for the model based on the Dynamic GTAP model and incorporating energy and emissions modules from GTAP-E, with some modifications described in this paper.

baseline.tab

This is a small tablo programme that generates 50-year baseline macro drivers and energy-related changes in form of shocks to corresponding variables. The macro drivers include population, skilled and unskilled labour, and total factor productivity projections as described in section XX of this paper. For this programme to work, the har-file associated with the logical file GTAPSETS and the *baseline.har* file described below should be placed in the same directory. Outputs are written into the file *blshocks.har*.

baseline.har

This file contains the raw data to be used for baseline shocks generations with baseline.tab tablo programme.

edatmaker.tab

This is a tablo programme that generates headers required for energy-environment modules of the model. Parameters related to number of simulation periods, energy substitution structure and emissions trade, as well as the modified elasticities of substitution, are written to file *eextra.har*, whereas the headers with updateable data (emissions, period number) to be transferred to the main data file are written to file *edat.har*.

2. Background

The idea for a long-term global economy simulation with particular emphasis on energy and climate issues came in context of projects that are carried out in multidisciplinary research groups including researchers using sophisticated energy system models, in particular the Global ETSAP/TIAM energy system model. The intention is to use the GTAP model to generate inputs for the drivers that are exogenous in the energy system models. Namely, this includes the industry outputs in the production sectors of the model.

The outputs of the energy system model on energy use on production sectors and consumption, as well as investment costs to new technologies, in turn, are then inserted to the GTAP simulations as exogenous variables, resulting in values for technical change variables reflecting energy efficiency, usage of different forms of primary energy and also technologies to directly reduce emissions. As this may affect the distribution of industry output by sector, the process is iterated.

As the timeline in energy system models reaches much further (typically e.g. until year 2100) than what is the usual horizon in CGE models, the exogenous macro variables for baseline have to be established. Moreover, such a long-run simulation is not without some fundamental concerns over the validity of the modelling and data approach, discussed further in section 5 of this paper. The simulations with GTAP model presented here do not extend beyond year 2050.

3. The model

The model is built on the Recursive Dynamic GTAP Version 3.4 (Ianchovichina & McDougall 2000) and incorporates the energy-capital substitution production structure as well as modules for carbon taxes and emissions trade from the GTAP-E model (Truong 2007). There are some technical changes required to the model code to improve the functionality of the energy and environment modules in dynamic simulations. Moreover, additional features are added to take into account non-fossil fuel energy sources and technologies that directly decrease emissions form fuel use (most notably, Carbon Capture and Storage). The most important modifications are described in this section.

Logical files

Standard base data, sets and parameters follow the logical file convention of the Dynamic GTAP model. For convenience, parameters and sets related to the energy and environment model are stored in a fifth logical file GTAPENV. List of the corresponding headers is in annex XX and there is a sample file *eextra.har* attached. However, those additional headers that are updated in each simulation period are included in the file corresponding to logical file GTAPDATA.

Period-specific dummy parameters

The GTAP-E model employs a range of dummy coefficients that determine the participation to national or international emissions trading for each sector and region. In the dynamic model, it is desirable to allow these parameters be different for each period. In the extra parameter file, these coefficients are stored in a header with an additional dimension for simulation periods.

The correct dummy coefficients are then selected from the parameter header with help of a period-specific multiplier vector. This requires an additional set for simulation periods, which must be manually modified to exactly mach the number of periods in current simulation experiment. An additional header is also needed in the updated data file for recording the number of current simulation period. The tablo code for this technical adjustment is documented in annex 1.

Technical change directly affecting emissions

In the long term, carbon capture and storage (CCS) technology is likely to become an important option for reducing the fossil fuel emissions. As this technology directly affects the amount of emissions from a given amount of fuel used, additional variables are introduced. Whilst the main impact of such technologies is likely to be on heavy industry and electricity production, the variables are determined for each energy commodity in all sectors, private household and government demands separately (respectively *a_ccsf*, *a_ccsp* and *a_ccsg*). The tablo code implementation on the emissions formulae is presented in annex 1.

Some other adjustments

In the GTAP-E version of Truong (2007), the emission variables (CO2TS_T, CO2NS_T, CO2SQ etc) are only defined for the relevant subsets of regions and sectors. This raises a minor technical inconvenience, because the composition of these subsets may change from period to period in the dynamic simulation, and therefore it would complicate for example combining the header array files with different period results, as the headers would have different sizes. To prevent this problem, all these variables are redefined to all regions. This does not appear to require other modifications, since the formulae already are ‘redundant’ in the way that they include the trade participation dummy as multiplier (TREG, TSEC), which renders the values for the regions not belonging to the relevant subset zeros.

The equation EV_DECOMPOSITION is modified in the same way as in the GTAP-E model, to include emissions trading and the energy nest composite changes.

The standard technical change variables (ao, af, afe) retain the simpler decomposition similar to the Dynamic GTAP model, with one regional and one sectoral (two-dimensional) component only. Naturally, the energy-specific technical change variables are also maintained.

4. Data issues

The aim of this project has been to make region and sector aggregation as flexible as possible and develop helper applications to facilitate making of new aggregations. There are data available that to large extent can be used for this purpose. Yet, certain issues require special attention.

Emissions data

Emissions data that is compatible with the GTAP-E is in Lee (2008) and in Ludena (2007). It is, in principle, rather straightforward to use these data for any desired aggregation. However, the database seems to have some accuracy issues (possibly due to limited number of decimals recorded) that become fatal if the aggregation includes small standalone regions. Namely, the ratios used to calculate CO_2 emission by sector and fuel may, in some cases, become infinitely small or excessively large due to inaccurate small numbers. Whilst this has little impact on overall results (as the numbers are very small to start with), it may, unfortunately, lead to fatal errors in the simulation algorithm.

To overcome the aforementioned problem, an adjusted dataset is created, where the emission data is balanced with the intermediate and household purchases data.

Parameters

The substitution elasticities for energy commodities in GTAP-E differ from those in standard GTAP applications, and these are also employed here. They are kept in the GTAPENV file instead of the normal parameter file. The CES between primary factors are defined two-dimensionally, separately for each region, unlike in standard GTAP. These estimates for energy commodities are only available for the regions in the original GTAP-E application, and the aggregation tools assumes them to be equal across the countries in those regions.

For agricultural products, region-specific estimates are available in GTAP-AGR aggregation, compiled in Ludena (2008). These are calibrated with the regional estimates used in GTAP-E and then used as base data for the aggregation programme.

5. Issues and further steps

Suitability of CGE for very long-run analysis: structural change not captured (esp. China)?

Inclusion of alternative energy forms.

6. Baseline scenarios

Two baselines with projections of macro variables have been constructed. A medium-term baseline covers years 2001-2020 by one year intervals, whereas a long-term baseline runs from 2001 to 2050. Both baselines were constructed for the 87 countries and regions following the GTAP database version 6 structure, and then aggregated to the regions used in the applications. In the examples presented in this paper and calibration with the ETSAP-TIAM energy system model, we are bound with the region and sector structure of the latter model (see annex XX).

The projections build on the Baseline Scenario for the Dynamic GTAP Model (Walmsley 2006). However, a number of modifications were required. Most importantly, the previously available baseline only covers the time period until 2020, and therefore is inadequate for the longer term simulations. Since the release of this baseline, some updated actual as well as forecasted data has become available also for the years before 2020, and the projections are adjusted accordingly. An attempt is made to identify usable forecasts covering the period exceeding to 2050 and incorporate these to the baseline projection. Further, some sources were replaced with alternative ones, especially for the data covering the European countries.

Data Sources for Macro Variable Projections

Projections were obtained for gross domestic product, productivity growth, population, total labour and skilled labour. Descriptions of this data are given below:

<u>Gross domestic product and productivity growth projections</u>

GDP projections were available from three sources. The World Economic Outlook Database (IMF 2008) covers 184 countries and years until 2013. European Commission (Carone et al. 2006) has produced long term GDP and productivity growth forecasts for 25 EU member countries, extending to year 2050. Poncet (2006) includes long-term growth estimates in 100 economies. In the long-term baseline, GDP growth driver was replaced with the total factor productivity growth estimates starting from period 2015-2020.

However, in the calibration exercise with the energy system model described in section 7 of this paper, we have reverted to TFP growth estimates that are compatible with the growth projections employed in recent International Energy Association (IEA) scenarii, to maintain the results comparable with the other related research.

<u>Population projections</u>

Three different sources were used to compile population growth projections. The World Population Prospects Database, year 2006 revision (United Nations 2008) covers 190 countries, and this is the source used in the Dynamic GTAP baseline (Walmsley 2006). However, for European countries, the figures were replaced by a recent EUROPOP Convergence Scenario (Eurostat 2008), which accounts better for the intra-European migration. Similarly, for Northern America, figures provided by the US Census Bureau (2008) were used. The latter was also used to cover some GTAP regions that are not included in the UN database (Taiwan and some Caribbean regions).

<u>Labour force projections</u>

Economically active population projections were obtained for 191 regions until 2020 from the LABORSTA database (ILO 2008). Additional long-term projections until 2050 were available for EU countries from Carone (2005) and for OECD countries from OECD data. For the rest of the world post 2020 years, regional labour force participation change estimates by CPB (1999) were used.

To calibrate the data from various sources, the labour force participation rates for working age population was calculated from inside each source, and the selected rates were then applied to the corresponding working age population projections in the compiled population dataset described above.

Skilled and unskilled labour projections

In order to split the labour force into skilled and unskilled, the estimates were based on projected skilled labour shares for 12 developed/developing regions over the period 1994 to 2050 obtained from the CPB (1999).

However, there are notable deviations from these paths, most importantly in case of China, as discussed more in detail below.

Energy efficiency

New technologies

7. Baseline results and calibration with the energy system model

Macroeconomic development

The projected annual average world population growth in period 2005–¬2050 is 0.77% and the total population reaches 9.2 billion by the end of the projection period. However, alternative population scenarios range from 8 to 11 billion. Due to demographic differences, the labour force growth can be lower or higher than the total population growth in each region, and on global level, an increased share of working age population is observed until 2020, after which it starts to decrease.

The total factor productivity growth estimates vary between 1% in some Western countries and up to 5% in fastest-growing Asian economies. This results in total annual GDP growth rates of up to 10% in countries like China and India. By the year 2050, the extreme growth figures are projected to come closer to those in developed economies, but the key question for the overall results is how fast this convergence is going to take place.

The scenarios presented here are built on the baseline drivers similar to those used in the latest IEA World Energy Outlook (IEA 2008). However, effects of alternative growth assumptions, in particular regarding productivity growth in China are also discussed. It should also be emphasised that the GTAP baseline does not include the effects of climate change on the economies, hence producing high growth results in the scenarios without any climate policies.

Increased demand for energy and food

The growth in macro drivers, and population in particular, triggers some fundamental changes in the world commodity markets. The products that are scarce and difficult to substitute become more expensive relative to other goods. This is particularly true for food and primary energy: whilst their share of the global value of industry output is gradually declining, their prices compared to other goods increase fast.

In rapidly industrialising regions, namely China, energy takes an increasing share of total industry output value until 2020, as illustrated by the figure below. Globally, however, in almost all regions the services and manufacturing with high value added are increasing their share.

Population and labour

The growth assumptions for population are based on scenarios by United Nations (UN 2006) and for total labour force on ILO (2008) and Carone (2005). Additional sources for predicting the skilled and unskilled labour shares include Walmsley (2006), Holz (2008) and CPB (1999). In the baseline, the annual average world population growth in period 2005–2050 is 0.77% and the total population reaches 9.2 billion by the end of the projection period, whilst alternative population scenarios range from 8 to 11 billion. Due to demographic differences, the labour force growth can be lower or higher than the total population growth in each region, and on global level, an increased share of working age population is observed until 2020, after which it starts to decrease. Another important trend is the increase of the labour skill levels, which is a particularly prominent factor in China, where the skilled labour force has doubled in every five years since year 2000, and is expected to continue to grow, though at somewhat lower rate. Whilst the China numbers are extreme, most developing countries are experiencing relatively high increase of skilled labour.

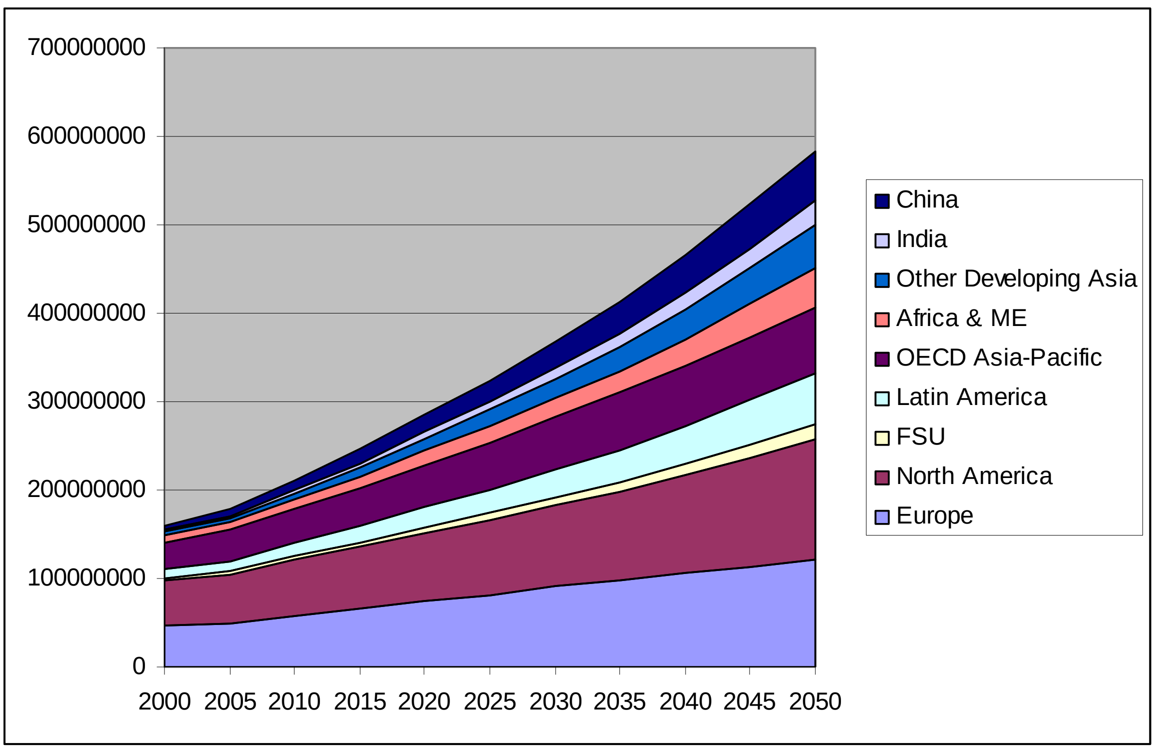

Figure: World GDP 2000-2050, results of the baseline simulation on long-run equilibrium growth path, not accounting for the impact of climate change.

Industry output

The results in the baseline run show that the value of global industry output in year 2050 is five times the value in 2005, which corresponds to an annual average growth rate of 3.64%. The annual world average GDP growth is about one percentage point below the industry output growth, ranging from 1.7% in Asia-Pacific OECD countries to 5.5% in India.

Whilst the global increase of production output is spread fairly evenly across sectors, there are significant regional differences. In 2005, developing countries produced 19% of the total world output but in 2050, their share will reach 41%. In other words, the developing countries will account for nearly half of the total world output growth 2005-2050. However, this growth mirrors the industrialisation of the regions that at present on one hand are predominantly agriculture producers, and on the other hand experience the fastest population growth. In the period 2005–2050, 70% of the global primary production increase and 56% of the global manufacture production increase will take place in the developing world, whereas the corresponding growth in service sectors is only 42%. At the same time, the OECD countries experience much lower growth, out of which 62% is attributable to service sectors. Thus, the world energy demand is shifting towards the developing regions.

Asia growth

As discussed above, the share of Developing Asia in the world economy will grow from 10% today to 25% in 2050 in the baseline scenario. In addition to the overall growth, one striking characteristic is the growth of skilled labour especially in China. The number of university graduates in China has been growing since early 1990's, when they were around one million, reaching 5 million new undergraduate degrees every year in 2005, twice the number in the USA. This has triggered an economic growth reaching annual 10%. Such high growth rates obviously have an impact on the global economy. Furthermore, in a long-run simulation, relatively small differences in assumptions will cumulatively result in significantly different outcomes. For example Holz (2006) projects China's GDP level to exceed that of the USA at latest by year 2033.

A similar, though less dramatic pattern, applies to the developing South-East Asia. India's education levels are presently higher than in rest of developing Asia, and they are not growing with the same speed. Due to its population size and existing stock of skilled labour, India is still an important factor in long-term global economic development.

ANNEX 1: TABLO codes

1. Code for counting simulation periods

```
!< Period counting and set (added JN)

   This section is needed in selecting certain period-specific parameters from a
   matrix containing data for all periods.
>!
Set
    PERIODS # periods in dynamic simulation #
    read elements from file GTAPENV header "PRDS";


Coefficient (non_parameter) ITERNUM # iteration count #;
! Prevent solution algorithms with multiple iterations from increasing period
  count with more than one !
Formula (initial) ITERNUM = 1;
Update (change) ITERNUM = 1;

Coefficient (non_parameter) PRDNUM # simulation period count #;
Read PRDNUM from file GTAPDATA header "PNUM";
Update (change) PRDNUM = 0 + if{ITERNUM=1, 1};


Coefficient (all,t,PERIODS) PRDDUMV(t) # Dummy vector for current period # ;
! This vector is used for selecting data corresponding to current period from
  a multi-period matrix !
Formula (all,t,PERIODS)
   PRDDUMV(t) = 0 + if{$POS(t,PERIODS)=PRDNUM, 1};
```

2. Code for selecting the current period dummy coefficient values for emissions trading participation

```
!
  Read in matrices containing trading participation parameters for all
  periods and select the data for current period. (added by JN)
!

Coefficient (all,j,PROD_COMM)(all,r,reg)(all,t,PERIODS)  TTSEC(j,r,t)
  # =1 if sector is Trading (dom. or int. market) # ;
Coefficient (all,r,reg)(all,t,PERIODS)                   TTCON(r,t)
  # =1 if HH is Trading (dom. or int. market) # ;
Coefficient (all,r,reg)(all,t,PERIODS)                   TTREG(r,t)
  # =1 if region is Trading (int. market) # ;

Read  TTSEC from file gtapenv header "TSEC";
Read  TTCON from file gtapenv header "TCON";
Read  TTREG from file gtapenv header "TREG";

Formula (initial, write updated value to file gtapdata header "TSEC")
   (all,j,PROD_COMM)(all,r,reg)
   TSEC(j,r) = sum[t,PERIODS, PRDDUMV(t)*TTSEC(j,r,t)];
Formula (initial, write updated value to file gtapdata header "TCON")(all,r,reg)
   TCON(r) = sum[t,PERIODS, PRDDUMV(t)*TTCON(r,t)];
Formula (initial, write updated value to file gtapdata header "TREG")(all,r,reg)
```

```
TREG(r) = sum[t,PERIODS, PRDDUMV(t)*TTREG(r,t)];
```

3. Modified code for including additional technical change related to carbon capture.

```
! linking CO2 emissions at the sectoral level to prod./cons.  activities !

! Following six equations augmented with carbon capture and storage (CCS)
  technology change variables a_ccsf, a_ccsp, a_ccsg, added by JN!

Variable (all,i,EGY_COMM)(all,j,PROD_COMM)(all,r,REG)
  a_ccsf(i,j,r) # CCS technology in firms #;
Variable (all,i,EGY_COMM)(all,r,REG)
  a_ccsp(i,r) # CCS technology in private consumption #;
Variable (all,i,EGY_COMM)(all,r,REG)
  a_ccsg(i,r) # CCS technology in goverment consumption #;

Equation (Linear) E_p_ECO2Dj (all,i,EGY_COMM)(all,j,PROD_COMM)(all,r,REG)
    p_CO2DF(i,j,r) = qfd(i,j,r) - a_ccsf(i,j,r);
Equation (Linear) E_p_ECO2IF (all,i,EGY_COMM)(all,j,PROD_COMM)(all,r,REG)
    p_CO2IF(i,j,r) = qfm(i,j,r) - a_ccsf(i,j,r);

Equation (Linear) E_p_ECO2DP (all,i,EGY_COMM)(all,r,REG)
    p_CO2DP(i,r) = qpd(i,r) - a_ccsp(i,r);
Equation (Linear) E_p_ECO2IP (all,i,EGY_COMM)(all,r,REG)
    p_CO2IP(i,r) = qpm(i,r) - a_ccsp(i,r) ;

Equation (Linear) E_p_ECO2DG (all,i,EGY_COMM)(all,r,REG)
    p_CO2DG(i,r) = qgd(i,r) - a_ccsg(i,r) ;
Equation (Linear) E_p_ECO2IG (all,i,EGY_COMM)(all,r,REG)
    p_CO2IG(i,r) = qgm(i,r) - a_ccsg(i,r) ;
```

ANNEX 2: The basic closure

```
! basic closure for GTAP-E Dyn
Exogenous
! --- standard GTAP-Dyn closure --------------------
    af
    afe(ENDWC_COMM,PROD_COMM,REG) !added!
    afereg afesec
    ams
    ao
    atall
    atm atf ats  atd
    au
    avadiff avareg
    dpgov dppriv
    dpsave !omit in savings version
    empl
    endwslack
    incomeslack
    pop
    profitslack
    psavewld
    qfactsup(ENDWNA_COMM,REG)
    SDKHAT SDRORT SDRORW SDTBALWORLD
    sqcgdsworld sqk  sqkworld
    swq_f swqh
    srorge
    swqhf swqht
    time
    tm tms
    to
    tp
    tradslack
    tx txs
!    twyr!added only for savings version!
! tfd tfm tpd tpm tgm tgd : blocked for CO2TAX-module
! ---E-module------------------------
afLab afKE afNELY afNCOL afener
! ---C-module------------------------
! non carbon tax on ENERGY commodities need to remain exogenous:
tpd_nc tpm_nc tgd_nc tgm_nc tfd_nc tfm_nc
! tax on NON-ENERGY commodities need to remain exogenous:
tpd(NEGY_COMM,REG) tpm(NEGY_COMM,REG)
tgd(NEGY_COMM,REG) tgm(NEGY_COMM,REG)
tfd(NEGY_COMM,PROD_COMM,REG)
tfm(NEGY_COMM,PROD_COMM,REG)
! ---T-module------------------------
c_INT_MARKCTAX c_DOM_MARKCTAX
c_SEC_CTAX c_CON_CTAX
p_CO2SQ p_CO2CQ p_CO2RQ
! ---CCS technology------------------
a_ccsf a_ccsp a_ccsg;
Rest endogenous;
```

Projected average annual growth rates (in %)

Total population

Region	2001-2020	2021-2050	*sources*
Denmark	0.29	0.14	*Eurostat*
Finland	0.30	-0.03	*Eurostat*
Norway and Iceland	0.63	0.40	*Eurostat*
Sweden	0.53	0.27	*Eurostat*
Germany	-0.05	-0.30	*Eurostat*
Rest of high income EU and EFTA	0.59	0.19	*Eurostat*
Middle income EU	-0.16	-0.40	*Eurostat*
Russia	-0.54	-0.68	*UN*
Rest of Europe and Central Asia	0.54	0.11	*UN*
Important oil producing countries	1.81	1.03	*UN*
African Rainforest Areas	2.57	1.91	*UN*
Rest of Africa and Middle East	2.23	1.53	*UN*
USA, Canada, high income Caribean, Greenland	0.86	0.68	*US Census Bureau*
Latin American Rainforest Areas	1.31	0.60	*US Census Bureau*
Rest of Latin America	1.04	0.52	*US Census Bureau*
China	0.56	-0.03	*US Census Bureau*
India	1.39	0.62	*US Census Bureau*
Asian and Pacific Rainforest Areas	1.17	0.51	*US Census Bureau*
Rest of low income Asia and Pacific	1.68	0.98	*US Census Bureau*
Australia and New Zealand	1.00	0.57	*US Census Bureau*
Rest of high income Asia	0.12	-0.46	*UN, US Census Bureau*

Skilled labour

Region	2001-2020	2021-2050	*sources*
Denmark	0.71	0.43	*ILO, Carone 2005, CPB 1999*
Finland	0.71	0.29	*ILO, Carone 2005, CPB 1999*
Norway and Iceland	1.05	0.47	*ILO, Carone 2005, CPB 1999*
Sweden	1.17	0.61	*ILO, Carone 2005, CPB 1999*
Germany	0.74	-0.30	*ILO, Carone 2005, CPB 1999*
Rest of high income EU and EFTA	1.30	0.36	*ILO, Carone 2005, CPB 1999*
Middle income EU	0.54	-0.68	*ILO, Carone 2005, CPB 1999*
Russia	-0.04	0.39	*ILO, CPB 1999*
Rest of Europe and Central Asia	1.49	0.46	*ILO, CPB 1999*
Important oil producing countries	4.84	1.72	*ILO, CPB 1999*
African Rainforest Areas	5.23	2.79	*ILO, CPB 1999*
Rest of Africa and Middle East	4.92	2.75	*ILO, CPB 1999*
USA, Canada, high income Caribean, Greenland	1.15	0.32	*ILO, OECD, CPB 1999*
Latin American Rainforest Areas	3.66	1.30	*ILO, CPB 1999*
Rest of Latin America	3.34	1.28	*ILO, CPB 1999*
China	1.58	1.17	*ILO, CPB 1999*
India	3.22	1.65	*ILO, CPB 1999*
Asian and Pacific Rainforest Areas	3.62	1.13	*ILO, CPB 1999*
Rest of low income Asia and Pacific	3.90	1.55	*ILO, CPB 1999*
Australia and New Zealand	1.41	0.44	*ILO, OECD, CPB 1999*
Rest of high income Asia	0.43	-0.10	*ILO, OECD, CPB 1999*

Unskilled labour

Region	2001-2020	2021-2050	*sources*
Denmark	0.08	-0.39	*ILO, Carone 2005, CPB 1999*
Finland	0.07	-0.53	*ILO, Carone 2005, CPB 1999*
Norway and Iceland	0.41	-0.35	*ILO, Carone 2005, CPB 1999*
Sweden	0.53	-0.21	*ILO, Carone 2005, CPB 1999*
Germany	0.11	-1.11	*ILO, Carone 2005, CPB 1999*
Rest of high income EU and EFTA	0.66	-0.46	*ILO, Carone 2005, CPB 1999*
Middle income EU	-0.09	-1.49	*ILO, Carone 2005, CPB 1999*
Russia	-0.67	-0.43	*ILO, CPB 1999*
Rest of Europe and Central Asia	0.66	-0.55	*ILO, CPB 1999*
Important oil producing countries	2.34	-0.05	*ILO, CPB 1999*
African Rainforest Areas	2.61	-0.18	*ILO, CPB 1999*
Rest of Africa and Middle East	2.45	-0.08	*ILO, CPB 1999*
USA, Canada, high income Caribean, Greenland	0.43	-0.56	*ILO, OECD, CPB 1999*
Latin American Rainforest Areas	1.34	-0.35	*ILO, CPB 1999*
Rest of Latin America	1.03	-0.38	*ILO, CPB 1999*
China	0.23	-0.51	*ILO, CPB 1999*
India	1.57	-0.25	*ILO, CPB 1999*
Asian and Pacific Rainforest Areas	1.08	-0.50	*ILO, CPB 1999*
Rest of low income Asia and Pacific	2.04	-0.18	*ILO, CPB 1999*
Australia and New Zealand	0.77	-0.38	*ILO, OECD, CPB 1999*
Rest of high income Asia	-0.21	-0.94	*ILO, OECD, CPB 1999*

GDP

Region	2001-2010	2011-2030	2031-2050	*sources*
Denmark	1.6	1.6	1.6	*Carone et al. 2006*
Finland	2.6	1.7	1.5	*Carone et al. 2006*
Norway and Iceland	2.5	1.9	1.8	*IMF, own calculations*
Sweden	2.6	2.4	1.8	*Carone et al. 2006*
Germany	1.1	1.4	1.2	*Carone et al. 2006*
Rest of high income EU and EFTA	2.3	1.8	1.3	*Carone et al. 2006*
Middle income EU	4.2	3.0	0.9	*Carone et al. 2006*
Russia	6.5	5.8	5.6	*IMF, own calculations*
Rest of Europe and Central Asia	6.5	5.2	4.8	*IMF, own calculations*
Important oil producing countries	5.2	6.0	6.5	*IMF, own calculations*
African Rainforest Areas	7.3	4.0	3.6	*IMF, own calculations*
Rest of Africa and Middle East	5.4	5.7	5.9	*IMF, own calculations*
USA, Canada, high income Caribean, Greenland	2.1	3.4	3.8	*IMF, own calculations*
Latin American Rainforest Areas	3.9	4.1	4.5	*IMF, own calculations*
Rest of Latin America	3.7	3.8	4.3	*IMF, own calculations*
China	10.0	10.0	10.1	*IMF, own calculations*
India	7.5	8.0	8.5	*IMF, own calculations*
Asian and Pacific Rainforest Areas	5.6	6.4	6.8	*IMF, own calculations*
Rest of low income Asia and Pacific	5.6	6.5	7.0	*IMF, own calculations*
Australia and New Zealand	3.2	3.4	3.5	*IMF, own calculations*
Rest of high income Asia	2.2	2.5	2.7	*IMF, own calculations*

Labour productivity

Region	2001-2010	2011-2030	2031-2050	*sources*
Denmark	1.9	1.8	1.7	*Carone et al. 2006*
Finland	2.1	2	1.7	*Carone et al. 2006*
Norway and Iceland			1.7	
Sweden	2.2	2.3	1.7	*Carone et al. 2006*
Germany	0.9	1.6	1.7	*Carone et al. 2006*
Rest of high income EU and EFTA	1.3	1.8	1.7	*Carone et al. 2006*
Middle income EU	3.5	3.1	1.9	*Carone et al. 2006*

TFE

Data coverage

GTAP Regions fully represented in Poncet (2006)

52 single-country, 2 multi-country regions

AUS	Australia
AUT	Austria
BEL	Belgium
BGD	Bangladesh
BGR	Bulgaria
BRA	Brazil
BWA	Botswana
CAN	Canada
CHE	Switzerland
CHL	Chile
CHN	China. People's Rep.
COL	Colombia
CYP	Cyprus
DEU	Germany
DNK	Denmark
ESP	Spain
FIN	Finland
FRA	France
GBR	United Kingdom
GRC	Greece
HKG	Hong Kong
HUN	Hungary
IDN	Indonesia
IND	India
IRL	Ireland
ITA	Italy
JPN	Japan
KOR	South Korea
LKA	Sri Lanka
MEX	Mexico
MOZ	Mozambique
MWI	Malawi
MYS	Malaysia
NLD	Netherlands
NZL	New Zealand
PER	Peru
PHL	Philippines
POL	Poland
PRT	Portugal
ROM	Romania
SGP	Singapore
SWE	Sweden

THA	Thailand
TUN	Tunisia
TUR	Turkey
TZA	Tanzania
UGA	Uganda
URY	Uruguay
USA	United States
VEN	Venezuela
ZAF	South Africa
ZMB	Zambia
ZWE	Zimbabwe

GTAP Region	**Countries covered**	**Coverage % of total**
XAP	Bolivia	38.89%
	Ecuador	61.11%
Total of region covered		*100.00%*
XEF	Iceland	6.41%
	Norway	93.59%
Total of region covered		*100.00%*

GTAP Regions partially represented in Poncet (2006)
10 multi-country regions partly covered
(country weights are shares of region's economically active / working age population)

GTAP Region	**Countries covered**	**Coverage % of total**
XCA	Costa Rica	12.09%
	El Salvador	18.70%
	Guatemala	27.22%
	Honduras	17.94%
	Nicaragua	13.72%
	Panama	9.66%
Total of region covered		*99.32%*
XFA	Barbados	1.53%
	Dominican Republic	33.42%
	Haiti	32.56%
	Jamaica	10.94%
	Trinidad and Tobago	5.53%
Total of region covered		*83.98%*
XME	Bahrain	0.52%
	Iran	39.44%
	Israel	4.12%
	Jordan	2.58%
	Kuwait	2.02%
	Syria	10.22%
Total of region covered		*58.90%*
XNF	Algeria	33.80%
	Egypt	60.24%

Total of region covered		*94.04%*
XOC	Fiji	10.63%
	Papua New Guinea	70.45%
Total of region covered		*81.08%*
XSA	Nepal	14.15%
	Pakistan	74.68%
Total of region covered		*88.83%*
XSC	Lesotho	41.72%
	Swaziland	19.80%
Total of region covered		*61.52%*
XSD	Congo. Dem. Rep.	75.23%
	Mauritius	1.97%
Total of region covered		*77.19%*
XSM	Guyana	10.63%
	Paraguay	81.86%
Total of region covered		*92.48%*
XSS	Benin	1.63%
	Cameroon	3.57%
	Central African	1.02%
	Congo	0.83%
	Gambia	0.34%
	Ghana	5.11%
	Guinea-Bissau	0.32%
	Kenya	8.11%
	Mali	2.39%
	Niger	2.81%
	Rwanda	2.11%
	Senegal	2.40%
	Sierra Leone	1.13%
	Togo	1.24%
Total of region covered		*33.01%*

GTAP Regions not represented in Poncet (2006)
16 single-country and 5 multi-country regions

ALB	Albania
ARG	Argentina
CZE	Czech Republic
EST	Estonia
HRV	Croatia
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MAR	Morocco
MDG	Madagascar
MLT	Malta
RUS	Russian Federation
SVK	Slovakia
SVN	Slovenia

TWN	Taiwan
VNM	Viet Nam
XER	Andorra Bosnia and Herzegovina Faroe Islands Gibraltar Macedonia, the former Yugoslav Republic of Monaco San Marino Serbia and Montenegro
XCB	Anguilla Aruba Cayman Islands Cuba Guadeloupe Martinique Montserrat Netherlands Antilles Turks and Caicos Virgin Islands, British
XNA	Bermuda Greenland Saint Pierre and Miquelon
XSE	Brunei Darussalam Cambodia Lao People's Democratic Republic Myanmar Timor Leste
XSU	Armenia Azerbaijan Belarus Georgia Kazakhstan Kyrgyzstan Moldova, Republic of Tajikistan Turkmenistan Ukraine Uzbekistan

References

Ahuja, V. and D. Filmer. (1995). "Educational Attainment in Developing Countries; New Estimates and projections Disaggregated by Gender," World Bank Policy Research Working Paper 1489, Washington, DC, July.

Carone G. (2005). *'Long-term labour force projections for the EU25 Member States: a set of data for assessing the impact of ageing'*, European Commission, Economic Papers No. 235, European Commission, Directorate General for Economic and Financial Affairs.

Carone, G., C. Denis, K. Mc Morrow, G. Mourre, and W. Röger (2006). *Long-term labour productivity and GDP projections for the EU25 Member States : a production function framework.* European Economy-Economic Papers, European Commission-DG ECFIN 253 (2006): pp. 1-92.

CPB. (1999). "WorldScan: the Core Version," CPB Netherlands Bureau for Economic Policy Analysis, December.

Eurostat (2008). EUROPOP convergence scenario, population forecast 2008-2050.
ILO (2008). LABORSTA Internet, Labour Statistics Database, Geneva. http://laborsta.ilo.org/

Holz, C.A.(2008),China's Economic Growth 1978-2025: What We Know Today about China's Economic Growth Tomorrow, *World Development 36:10*, pp 1665-1691

IMF (2008). World Economic Outlook Database.
http://www.imf.org/external/pubs/ft/weo/2008/01/weodata/index.aspx

Poncet, S. (2006). "The Long Term Growth Prospects of the World Economy: Horizon 2050", CEPII Working Papers No 2006-16, Centre d'études prospectives et d'informations internationales, Paris.

United Nations (2006). World Population Prospects: The 2006 revision population database, New York. http://esa.un.org/unpp/

US Census Bureau (2008). International Data Base (IDB),
http://www.census.gov/ipc/www/idb/tables.html

Walmsley, T. (2006). *A Baseline Scenario for the Dynamic GTAP Model*, Center for Global Trade Analysis, Purdue University.
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2204

Dimaranan, Betina V., Editor (2006). *Global Trade, Assistance, and Production: The GTAP 6 Data Base*, Center for Global Trade Analysis, Purdue University.

Truong, T (2007): GTAP-E: An Energy-Environmental Version of the GTAP Model with Emission Trading - USER'S GUIDE
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2509

Ianchovichina, E. and R. McDougall (2000): Theoretical Structure of Dynamic GTAP,
GTAP Technical Paper No. 17,

December 2000

McDougall, R. and H-L Lee (2006): GTAP 6 Data Base Documentation - Chapter 17: An Energy Data Base for GTAP.
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=1951

Burniaux, J-M and T. Truong (2002): GTAP-E: An Energy-Environmental Version of the GTAP Model, GTAP Technical Paper No. 16,
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=923

Sands, R., M-K Kim and A. Fawcett (2007): Extending GTAP Data for Climate Policy Analysis, Presented at the 10th Annual Conference on Global Economic Analysis, Purdue University, USA.
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2411

Lee H-L (2008) The database is based on CO2 emissions data by in "An Emissions Data Base for Integrated Assessment of Climate Change Policy Using GTAP":
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=1143

Ludena, C (2007) CO2 Emissions by fuel and user for GTAP-E,
https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2508