Appendices

Appendix 1

1. COUNTRIES THAT HAVE DECOUPLED ECONOMIC GROWTH FROM GREENHOUSE GAS EMISSIONS

In a green economy it is said that economic activity is decoupled from greenhouse gas (GHG) emissions. At the first level, this means that economic activity is decoupled from the GHG emissions embedded in the *production* of goods and services. At the second level, and in open economies, this means that economic activity is decoupled from the GHG emissions embedded in the *consumption* of goods and services. Economic growth is therefore compared with the growth in production-based emissions to identify countries that have decoupled production:

- Using data from the *World Development Indicators* (World Bank, 2017), country-specific trends are constructed from 1995 to 2012, country-level statistics for annual per capita GDP and annual per capita GHG emissions.
- Using OLS regression models, the average annual growth is estimated in per capita GDP and per capita GHG emissions (in per cent). For each country c, we estimate:

$$logGDP_{c,y}=\beta_{0,c}+\beta_{1,c}\,year_y+e_{c,y}$$

and

$$logGHG_{c,y}=\gamma_{0,c}+\gamma_{1,c}\,year_y+e_{c,y}$$

where $\beta_{1,c}$ and $\gamma_{1,c}$ are each country's average annual percentage changes in per capita GDP and GHG emissions, respectively.

- Countries with $\beta_{1,c}>0$ and $\gamma_{1,c}<0$ are countries that experienced economic growth in the 1995–2012 period and reduced their per capita emissions during that period. These countries decoupled economic growth from production-based emissions.

Of the subset of countries that decoupled economic growth from production-based emissions, those that also decoupled from consumption-based emissions are identified as follows:

- Using historical data from the National Footprint Accounts covering the years 1960–2012, augmented by 2013 data (Global Footprint Network, 2016 and 2017), country-specific annual carbon consumption-based emissions trends are constructed.
- Using OLS regressions, the average annual change in the carbon footprint is estimated:

$$logCFoot_{c,y}=\mu_{0,c}+\mu_{1,c}year_y+e_{c,y}$$

- Countries with $\beta_{1,c}>0$, $\gamma_{1,c}<0$ and $\mu_{1,c}<0$ are countries that decoupled economic growth from production-based emissions and consumption-based emissions.

2. THE RELATIONSHIP BETWEEN EMPLOYMENT OUTCOMES AND DECOUPLING GDP GROWTH AND EMISSIONS

Figure 1.5, analysing the relationship between employment outcomes and the ability of countries to decouple GHG emissions from GDP, measures the correlation between decent work indicators and GHG emissions for countries worldwide with the data available between 1995 and 2014. Regression models estimate

$$logGHG_{y,c} = logEmp_{y,c} + c + y + e_{y,c}$$

as the marginal model where $logGHG_{y,c}$ are country c's GHG emissions per capita in year y and c and y are country and annual fixed effects, respectively. We also estimate

$$logGHG_{y,c} = logEmp_{y,c} + logGDP_{y,c} + logEInt_{y,c} + logPop_{y,c} + logUrban_{y,c} + c + y + e_{y,c}$$

as the conditional model, which adds controls for log GDP per capita, log energy intensity, log population and the log share of the urban population. For both the marginal and conditional models, one distinct model is estimated for each employment outcome, namely, working poverty (the percentage of workers living in extreme or moderate working poverty who live on less than US$3.10 PPP per day), the labour share of income, the female labour participation rate, the employment-to-population ratio and interaction effects to evaluate the sectoral distribution of employment, and self-employment (the percentage of workers who are employers, own-account workers, contributing family workers or members of producer cooperatives).

Results hold when the regressions are carried out separately for high-income, upper middle-income, lower middle-income and low-income countries. Results also hold when the regressions are carried out separately for coupled and decoupled countries. For results to hold within each country categorization, outlier cases are eliminated: Equatorial Guinea (average annual percentage change in GHG emissions of 54.8 and average annual percentage change in GDP per capita of 19.7), Afghanistan (20.4, 4.6), Angola (13.8, 4.4), Bosnia and Herzegovina (12.3, 11.7), Lao People's Democratic Republic (10.4, 5.3), Mozambique (9.5, 5.5) and Eswatini (9.4, 2.0).

Table A1.1 shows the regression results for the full-country model:

Table A1.1

Relationship between employment outcomes and GHG emissions

a. Working poverty

	Marginal	Conditional
Working poverty	–0.703***	–0.185***
	(0.0648)	(0.0546)
GDP growth		1.254***
		(0.0344)
Population growth		0.831***
		(0.0604)
Energy intensity		0.789***
		(0.0249)
Share of urban population		0.0780
		(0.172)
Constant	0.0732**	–25.24***
	(0.0360)	(1.117)
Year FE	*YES*	*YES*
Country FE	*YES*	*YES*
R-squared	*0.302*	*0.607*
No. countries	*121*	*121*
No. observations	*2233*	*2233*

b. Labour share of income

	Marginal	Conditional
Labour share of income	–0.302***	–0.0362
	(0.113)	(0.0867)
GDP growth		1.108***
		(0.0285)
Population growth		0.508***
		(0.0415)
Energy intensity		0.722***
		(0.0250)
Share of urban population		0.810***
		(0.156)
Constant	0.913***	–19.07***
	(0.0650)	(0.762)
Year FE	*YES*	*YES*
Country FE	*YES*	*YES*
R-squared	*0.110*	*0.500*
No. countries	*126*	*126*
No. observations	*2402*	*2402*

Table A1.1 (cont'd)

c. Female labour participation rate

	Marginal	Conditional
Female labour participation rate	–2.072***	–0.724***
	(0.317)	(0.234)
GDP growth		1.198***
		(0.0254)
Population growth		0.552***
		(0.0387)
Energy intensity		0.788***
		(0.0209)
Share of urban population		0.772***
		(0.138)
Constant	1.202***	–20.34***
	(0.126)	(0.713)
Year FE	*YES*	*YES*
Country FE	*YES*	*YES*
R-squared	*0.150*	*0.555*
No. countries	*170*	*170*
No. observations	*3 170*	*3 170*

d. Employment-to-population ratio

	Marginal	Conditional
Employment-to-population ratio	–1.798***	–0.174
	(0.178)	(0.136)
Employment-to-population ratio × Industry	4.383***	0.501***
	(0.232)	(0.188)
Employment-to-population ratio × Services	1.891***	–0.783***
	(0.180)	(0.146)
GDP growth		1.229***
		(0.0241)
Population growth		0.481***
		(0.0364)
Energy intensity		0.769***
		(0.0203)
Share of urban population		0.751***
		(0.135)
Constant	0.530***	–19.45***
	(0.0988)	(0.652)
Year FE	*YES*	*YES*
Country FE	*YES*	*YES*
R-squared	*0.230*	*0.587*
No. countries	*177*	*177*
No. observations	*3473*	*3473*

e. Self-employment

	Marginal	Conditional
Self employment	–1.601***	0.0935
	(0.139)	(0.114)
GDP growth		1.305***
		(0.0345)
Population growth		0.858***
		(0.0609)
Energy intensity		0.791***
		(0.0256)
Share of urban population		0.0987
		(0.174)
Constant	0.618***	–26.23***
	(0.0780)	(1.144)
Year FE	*YES*	*YES*
Country FE	*YES*	*YES*
R-squared	*0.307*	*0.605*
No. countries	*121*	*121*
No. observations	*2233*	*2233*

Notes: Standard errors in parentheses. A marginal and conditional time series (1995–2014) regression is estimated for each decent work indicator. All regression models consider yearly logGHG emissions per capita as the dependent variable and the decent work indicator as the independent variable. All models include country and year fixed effects. The marginal model includes only the relationship between each decent work indicator and logGHG emissions per capita. The conditional model adds controls for logGDP, log population, log energy intensity and the log share of the urban population. The model for employment shares by sector includes agriculture as the reference category. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: ILO calculations based on World Development Indicators, Penn World Tables and ILOSTAT.

3. THE CARBON AND RESOURCE INTENSITY OF EMPLOYMENT

For GHG emissions (carbon) and each resource (material, freshwater and land), the total emissions (in Kt) or resources (in Kt, billion m^3 or thousand Ha) are estimated that are associated with each employed person. In particular:

- for the carbon intensity of employment, each region's total GHG emissions (World Development Indicators) are divided by its total employment in thousands (ILO-modelled estimates) (ILOStat);
- for the material intensity of employment, each region's total material extraction (Material Flows Data) is divided by its total employment in thousands (ILO-modelled estimates) (ILOStat);
- for the freshwater intensity of employment, each region's total freshwater withdrawals (World Development Indicators) are divided by its total employment in thousands (ILO-modelled estimates) (ILOStat); and
- for the land use of employment, each region's total land use (FAOStat) is divided by its total employment in thousands (ILO-modelled estimates) (ILOStat).

4. WORKING-LIFE YEARS LOST DUE TO HUMAN-INDUCED DISASTERS

The estimate of working-life years lost due to disasters adapts Noy's (2014) methodology to the world of work. It takes into account the fact that people do not work during their entire life and that not all the population works. Noy estimates a benchmark index for life years lost due to disasters whereby

$$Lifeyears = L(M, A^{death}, A^{exp}) + I(N) + DAM(Y,P)$$

- $L(M, A^{death}, A^{exp}) = M(A^{exp} - A^{med})$ is the number of years lost due to mortality as a result of events, calculated as the difference between age at death and life expectancy. In global data sets, information about the age at death is not available, so the median age of the population (A^{med}) is used instead.
- $I(N) = eTN$ is the cost function associated with people who were injured or otherwise affected by the disaster, which follows the WHO (2013) methodology for calculating disability-adjusted life years (DALYs). The coefficient e is the "welfare-reduction weight" that is associated with being exposed to a disaster. The WHO weighting is adopted for disability associated with "generic uncomplicated disease: anxiety about diagnosis" (e=0.054). $T(=3\ years)$ is the time it takes an affected person to return to normality or for the impact of the disaster to disappear, while N is the number of people affected.
- $DAM(Y,P) = Y(1-c) \times pcGDP^{-1}$ estimates the number of life years lost as a result of the damage to capital assets and infrastructure (the opportunity cost of spending human resources (effort) on the reconstruction of the destroyed assets). Y is the amount of financial damage usually indicated in information about disaster impacts. P is the monetary amount obtained in a full year of human effort. Income per capita ($pcGDP$) is used as an indicator of the cost of human effort, but discounted by 75 per cent (c) to account for the observation that much time is spent in activities that are not related to work.

The index is adapted to relate better to the world of work and considers only disasters caused or enhanced by human intervention in the environment (anthropogenic disasters). In practice, we estimate:

$$Worklifeyears = [L(M, A^{death}, A^{retirement}) + I(N) + DAM(Y,P)]e$$

Noy's approach is adapted by measuring $A^{retirement}$ instead of A^{exp} because people are not expected to continue working beyond the age of 65. When a country's life expectancy is higher than 65, $A^{retirement}$ = 65, otherwise $A^{retirement} = A^{exp}$ is used.

In addition, the final result is weighted by the employment-to-population ratio (e) to take into account the proportion of a country's population that works.

Finally, disasters and natural hazards in the EM-DAT Disaster Database are only considered when they are caused or enhanced by human intervention in the environment or environmental degradation. This includes meteorological (storms, fog, extreme temperature), hydrological (floods, landslides, wave action), climatological (drought, glacial lake outburst, wildfires), biological (insect infestation) and certain technological (industrial or miscellaneous accidents) hazards. Estimates do not include casualties, people affected or damages resulting from geophysical (earthquake, mass movement, volcanic activity), biological (viral, bacterial, parasitic, fungal or prion disease epidemics, animal accidents), extraterrestial (impact, space weather) or certain technological (transport accidents) hazards.

5. THE IMPACT OF HEAT STRESS IN THE WORLD OF WORK

The methodological details for labour impact analysis follow Kjellstrom et al. (2017). The analysis of the projected impact of climate change on heat stress is based on grid cell data (0.5 x 0.5 degrees or 50 x 50 km at the Equator) for climate variables combined with population size estimates for four age groups (0 to 4 years, 5 to 14, 15 to 64 and 65 years or older) and employment distribution by broad economic sector.

The climate data use 30-year averages, identified by their mid-points: 1995, 2025, 2055 and 2085. The data for 2085, for example, draw on the average projected temperatures for each grid cell between 2071 and 2099. The HadGEM2-ES (Martin et al., 2011) and GFDL-ESM2M (Dunne et al., 2012 and 2013) provide the high- and low-end climate data and projections. These two models represent the range of 25 models used in the most recent assessments by the Intergovernmental Panel on Climate Change (IPCC, 2013). This report uses the average of the two, avoiding the calculation of heat stress impact across all the various climate projections available.[1] Most models correct bias in the temperature with measured data from weather stations over a long historical period. The bias correction in this report also corrects for humidity, which is a relevant parameter in assessing the human health risks of temperature.

The results shown in the report use future modelled estimates for representative GHG pathways RCP2.6 (ibid.). Pathway RCP2.6 gives a mean global temperature increase of 1.5°C by the end of the century.

Following Kjellstrom et al. (2017) and Kjellstrom and McMichael (2014), the heat stress index (the Wet Bulb Globe Temperature (WBGT) in degrees Celsius (°C)) is calculated by combining climate temperature (°C) and humidity (dew point, in °C) assuming air movement over the skin at 1 m/s (the speed at which arms or legs move when working) and in the shade or indoors without air conditioning. The heat stress index for work in the sun in the afternoon adds 2°C to the in-shade WBGT. Estimates of temperature and WBGT based on monthly mean temperature, and estimates of temperature and WBGT based on daily maximum temperature are used to derive the typical hourly distribution of heat levels.

The population data are based on United Nations population estimates and assessments of age distribution from the International Institute for Applied Systems Analysis (Lutz, Butz and Samir, 2014). For grid cells on the boundaries of regions or countries, the estimated population is distributed in the same proportion as the land distribution.

Data on workforce distribution in agriculture, industry and services at the country and subregional levels come from ILO *Key Indicators of the Labour Market* (ILO, 2015).

Following Kjellstrom et al. (2017), the results estimate heat stress approximate exposure–response relationships for work intensities at 200W (clerical or light physical work), 300W (moderate physical work in manufacturing) and 400W (heavy physical work in agriculture or construction). They allow for the conversion of an environmental heat level (expressed as WBGT) to a percentage of unavailable work capacity if the worker reduces work intensity to avoid clinical health effects. The loss of work hours is calculated using the exposure–response equations for each daylight hour of a month or a year for each grid cell. The lost hours per person in different work types are then added up for all grid cells in a geographic area (e.g. subregions). The number of lost hours in each occupation type is also added and compared with the total hours available for work in each daylight 12-hour period.

No matter what the conditions, some work is always possible because, if the person does not release any heat at all, the specific heat of the body (3470 J/(kg$\times$°C)) allows at least 6 minutes in the hour before the core temperature reaches an intolerable 39°C. Also, even when working continuously, it is necessary to take "micro-breaks" to stretch, go to the toilet, or simply relax. It is assumed that 10 per cent of work time is used in this way. In the impact assessments, a cut-off is used at 10 per cent time lost (full work up to this level) and 90 per cent time lost (10 per cent of work, or 6 minutes, which is always possible).

With the large population in several regions and the calculated fractions of hot days at a very hot level based on mathematical functions, relatively large numbers of lost work hours can emerge from these fractions of days or hours. To avoid overestimating the hours affected by heat, the mathematical functions are trimmed at 1 per cent, providing conservative estimates, especially in temperate regions.

1. Both the HadGEM2-ES and the GFDL-ESM2M models are available at the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP): www.isimip.org.

Appendix 2

1. USING MULTIREGIONAL INPUT–OUTPUT TABLES TO ESTIMATE THE EMPLOYMENT EFFECTS IN A GREEN ECONOMY

This appendix provides methodological details on the procedure used to estimate the number of jobs created and destroyed, as well as the change related to wages, emissions and skills, and gender composition of the economy under certain scenarios associated with a low-carbon and resource-efficient economy. It first describes the data set, the general methodological approach and the specific assumptions used in each scenario.

Data

Exiobase is a multiregional input–output and supply-and-use table (MRIO) and reports the interlinkages between final consumption, the flow of intermediate and final goods and factor inputs into production. The environmental and socio-economic extensions to these databases allow analysis of the corresponding impacts along global value chains resulting from changes in global production networks. Exiobase covers 163 industries (for the symmetric input–output tables) and 200 products (for the supply-and-use tables) across 44 countries and five rest-of-the-world regions. It reports total employment, total female employment, total employment by skills level, vulnerable employment and total GHG emissions for each sector in each country, which is of special relevance to the present report.[1]

Tukker et al. (2013) and Wood et al. (2015) provide more information on Exiobase and its potential uses. Simas et al. (2014) provide a description of the employment and vulnerable employment accounts in the context of MRIO tables.

As described in Simas et al. (2014), Exiobase constructs labour inputs from national labour force surveys gathered from ILOStat, and a combination of labour force and industrial surveys in national accounts, obtained from the OECD STAN database. Labour data from the ILO consist of 39 economic sectors, while STAN data cover up to 60 industries, which provides a better allocation for economic output in the MRIO sectors. Labour inputs were disaggregated from broad economic sectors into industries in the MRIO according to the compensation of employees from the model. The disaggregation was made under the assumption that average wages and hours worked would be similar between all workers within a broad economic sector or industry.

Vulnerable employment in Exiobase follows ILO definitions, which include unpaid contributing family workers and own-account workers. The ILO and the OECD provide sector-level data on both employment and paid employees for all countries in the Exiobase. A weighted average ratio of paid employees per total employment for countries in the region for three broad sectors (agriculture, industry and services) identifies vulnerable employment in each of the five rest-of-the-world regions. Labour inputs in the MRIO model are divided into three skill levels (low, medium and high). The skill level of occupations is identified such that low-skilled occupations are all ISCO code 9 occupations, medium-skilled occupations are all ISCO code 4, 5, 6, 7 and 8 occupations, and high-skilled occupations are all ISCO code 1, 2 and 3 occupations. ILO sectoral data on occupations for all countries in Exiobase are used to construct the number of workers at each skill level in each sector. For the rest-of-the-world regions, each industry has a weighted average distribution of skill levels in total employment for three broad sectors: agriculture, industry and services.

Exiobase v3 maps the world economy in 2011, but has been updated to 2014 (Stadler et al., 2018). Projections up to 2030 combine International Monetary Fund (IMF) GDP projections to 2022 with the International Energy Agency (IEA) regional growth projections to 2030. Except for the changes modelled in the scenarios – as described below – the basic trade and country-specific sectoral structure of the world economy remains as described by the IMF projections (IEA, 2015; IMF, 2017).

Although analyses are carried out with the disaggregated table, the results in this report are aggregated by industry (agriculture, construction, fossil fuels and nuclear electricity production, manufacturing, mining, renewable-energy electricity production, services, utilities, and waste management and recycling), to facilitate reporting. Results are also aggregated at the regional level (Africa, Americas, Asia, Europe and Middle East). Due to data constraints, Exiobase regions differ slightly from ILO regional groupings. Table A2.1 shows the industry aggregation used in the report.

1. Exiobase is available through the project's website: www.exiobase.eu .

Table A2.1

Exiobase industry aggregation used in the report

Industries	Aggregated industry
Cultivation of paddy rice	Agriculture
Cultivation of wheat	Agriculture
Cultivation of cereal grains n.e.c.	Agriculture
Cultivation of vegetables, fruit, nuts	Agriculture
Cultivation of oil seeds	Agriculture
Cultivation of sugar cane, sugar beet	Agriculture
Cultivation of plant-based fibers	Agriculture
Cultivation of crops n.e.c.	Agriculture
Cattle farming	Agriculture
Pig farming	Agriculture
Poultry farming	Agriculture
Meat animals n.e.c.	Agriculture
Animal products n.e.c.	Agriculture
Raw milk	Agriculture
Wool, silk-worm cocoons	Agriculture
Manure treatment (conventional), storage and land application	Agriculture
Manure treatment (biogas), storage and land application	Agriculture
Forestry, logging and related service activities	Agriculture
Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing	Agriculture
Mining of coal and lignite; extraction of peat	Mining
Extraction of crude petroleum and services related to crude oil extraction, excluding surveying	Mining
Extraction of natural gas and services related to natural gas extraction, excluding surveying	Mining
Extraction, liquefaction and regasification of other petroleum and gaseous materials	Mining
Mining of uranium and thorium ores	Mining
Mining of iron ores	Mining
Mining of copper ores and concentrates	Mining
Mining of nickel ores and concentrates	Mining
Mining of aluminium ores and concentrates	Mining
Mining of precious metal ores and concentrates	Mining
Mining of lead, zinc and tin ores and concentrates	Mining
Mining of other non-ferrous metal ores and concentrates	Mining
Quarrying of stone	Mining
Quarrying of sand and clay	Mining
Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	Mining
Processing of meat cattle	Manufacturing
Processing of meat pigs	Manufacturing
Processing of meat poultry	Manufacturing
Production of meat products n.e.c.	Manufacturing
Processing of vegetable oils and fats	Manufacturing
Processing of dairy products	Manufacturing
Processed rice	Manufacturing
Sugar refining	Manufacturing
Processing of food products n.e.c.	Manufacturing
Manufacture of beverages	Manufacturing
Manufacture of fish products	Manufacturing
Manufacture of tobacco products	Manufacturing
Manufacture of textiles	Manufacturing
Manufacture of wearing apparel; dressing and dyeing of fur	Manufacturing
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harnesses and footwear	Manufacturing
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Manufacturing
Reprocessing of secondary wood material into new wood material	Waste mgt. and recycling
Pulp	Manufacturing
Reprocessing of secondary paper into new pulp	Waste mgt. and recycling

Table A2.1 (cont'd)

Industries	Aggregated industry
Paper	Manufacturing
Publishing, printing and reproduction of recorded media	Manufacturing
Manufacture of coke oven products	Manufacturing
Petroleum refinery	Manufacturing
Processing of nuclear fuel	Manufacturing
Plastics, basic	Manufacturing
Reprocessing of secondary plastic into new plastic	Waste mgt. and recycling
N-fertilizer	Manufacturing
P- and other fertilizers	Manufacturing
Chemicals n.e.c.	Manufacturing
Manufacture of rubber and plastic products	Manufacturing
Manufacture of glass and glass products	Manufacturing
Reprocessing of secondary glass into new glass	Waste mgt. and recycling
Manufacture of ceramic goods	Manufacturing
Manufacture of bricks, tiles and construction products, in baked clay	Manufacturing
Manufacture of cement, lime and plaster	Manufacturing
Reprocessing of ash into clinker	Waste mgt. and recycling
Manufacture of other non-metallic mineral products n.e.c.	Manufacturing
Manufacture of basic iron and steel and of ferro-alloys and first products thereof	Manufacturing
Reprocessing of secondary steel into new steel	Waste mgt. and recycling
Precious metals production	Manufacturing
Reprocessing of secondary precious metals into new precious metals	Waste mgt. and recycling
Aluminium production	Manufacturing
Reprocessing of secondary aluminium into new aluminium	Waste mgt. and recycling
Lead, zinc and tin production	Manufacturing
Reprocessing of secondary lead into new lead, zinc and tin	Waste mgt. and recycling
Copper production	Manufacturing
Reprocessing of secondary copper into new copper	Waste mgt. and recycling
Other non-ferrous metal production	Manufacturing
Reprocessing of secondary other non-ferrous metals into new other non-ferrous metals	Waste mgt. and recycling
Casting of metals	Manufacturing
Manufacture of fabricated metal products, except machinery and equipment	Manufacturing
Manufacture of machinery and equipment n.e.c.	Manufacturing
Manufacture of office machinery and computers	Manufacturing
Manufacture of electrical machinery and apparatus n.e.c.	Manufacturing
Manufacture of radio, television and communication equipment and apparatus	Manufacturing
Manufacture of medical, precision and optical instruments, watches and clocks	Manufacturing
Manufacture of motor vehicles, trailers and semi-trailers	Manufacturing
Manufacture of other transport equipment	Manufacturing
Manufacture of furniture; manufacturing n.e.c.	Manufacturing
Recycling of waste and scrap	Waste mgt. and recycling
Recycling of bottles by direct reuse	Waste mgt. and recycling
Production of electricity by coal	Fossil and nuclear
Production of electricity by gas	Fossil and nuclear
Production of electricity by nuclear	Fossil and nuclear
Production of electricity by hydro	Renewables
Production of electricity by wind	Renewables
Production of electricity by petroleum and other oil derivatives	Fossil and nuclear
Production of electricity by biomass and waste	Renewables
Production of electricity by solar photovoltaics	Renewables
Production of electricity by solar thermal	Renewables
Production of electricity by tide, wave, ocean	Renewables
Production of electricity by geothermal	Renewables
Production of electricity n.e.c.	Renewables
Transmission of electricity	Utilities

Table A2.1 (cont'd)

Industries	Aggregated industry
Distribution and trade of electricity	Utilities
Manufacture of gas; distribution of gaseous fuels through mains	Utilities
Steam and hot water supply	Utilities
Collection, purification and distribution of water	Utilities
Construction	Construction
Reprocessing of secondary construction material into aggregates	Waste mgt. and recycling
Sale, maintenance, repair of motor vehicles, motor vehicle parts, motorcycles, motorcycle parts and accessories	Services
Retail sale of automotive fuel	Services
Wholesale trade and commission trade, except of motor vehicles and motorcycles	Services
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	Services
Hotels and restaurants	Services
Transport via railways	Services
Other land transport	Services
Transport via pipelines	Services
Sea and coastal water transport	Services
Inland water transport	Services
Air transport	Services
Supporting and auxiliary transport activities; activities of travel agencies	Services
Post and telecommunications	Services
Financial intermediation, except insurance and pension funding	Services
Insurance and pension funding, except compulsory social security	Services
Activities auxiliary to financial intermediation	Services
Real estate activities	Services
Renting of machinery and equipment without operator and of personal and household goods	Services
Computer and related activities	Services
Research and development	Services
Other business activities	Services
Public administration and defence; compulsory social security	Services
Education	Services
Health and social work	Services
Incineration of waste: Food	Waste mgt. and recycling
Incineration of waste: Paper	Waste mgt. and recycling
Incineration of waste: Plastic	Waste mgt. and recycling
Incineration of waste: Metals and inert materials	Waste mgt. and recycling
Incineration of waste: Textiles	Waste mgt. and recycling
Incineration of waste: Wood	Waste mgt. and recycling
Incineration of waste: Oil/hazardous waste	Waste mgt. and recycling
Biogasification of food waste, incl. land application	Waste mgt. and recycling
Biogasification of paper, incl. land application	Waste mgt. and recycling
Biogasification of sewage sludge, incl. land application	Waste mgt. and recycling
Composting of food waste, incl. land application	Waste mgt. and recycling
Composting of paper and wood, incl. land application	Waste mgt. and recycling
Waste water treatment, food	Waste mgt. and recycling
Waste water treatment, other	Waste mgt. and recycling
Landfill of waste: Food	Waste mgt. and recycling
Landfill of waste: Paper	Waste mgt. and recycling
Landfill of waste: Plastic	Waste mgt. and recycling
Landfill of waste: Inert/metal/hazardous	Waste mgt. and recycling
Landfill of waste: Textiles	Waste mgt. and recycling
Landfill of waste: Wood	Waste mgt. and recycling
Activities of membership organizations n.e.c.	Services
Recreational, cultural and sporting activities	Services
Other service activities	Services
Private households with employed persons	Services
Extra-territorial organizations and bodies	Services

Methods

Given that MRIO tables record the flow of intermediate goods and services in the world economy, they map the inter-industry linkages within an economy. MRIOs capture the indirect effects (changes in other industries, e.g. coal mining) of changes in one specific industry (e.g. the electricity generation sector). This logic can be extended to the estimation of effects on industry-specific employment and wages, as well as on skills demand, gender composition at the industry level and environmental impact (e.g. GHG emissions, as well as land, water and resource use).

If, for example, 10 per cent of the inputs into the car industry are provided by the steel industry and the steel industry needs ten employees to produce one unit of output, then one employee (= 10 per cent of ten employees) in the steel industry is (indirectly) employed because of the production of one unit in the car industry.

Using the common input–output notation the indirect employment effect of one unit of production of industry j is calculated as

$$\underbrace{e_j^{ind}}_{\substack{\text{indirect}\\\text{employment}}} = \underbrace{\mathbf{e'Li}_j}_{\substack{\text{total}\\\text{employment}}} - \underbrace{e_j}_{\substack{\text{direct}\\\text{employment}}}$$

where $\mathbf{e}$ is a vector of direct employment per unit of output for all industries, $\mathbf{L}$ is the Leontief inverse, $\mathbf{i}_j$ is a vector where all entries are equal to zero except the entry corresponding to industry j which equals 1, and e_j is the direct employment per unit of output of industry j.

As employment is recorded in the value added block of the MRIO, this logic can be extended to other records in the MRIO, including vulnerable employment, employment by gender and skill level or the block of environmental accounts, as is the case for GHG emissions.

Miller and Blair (2009) provide more details on the use of input–output tables.

Applying input–output data in a scenario framework requires consideration of many factors. Basic input–output scenarios imply a series of direct and exogenous changes in final demand and the production structure, i.e. technological change (Koning et al., 2016; Wiebe, 2016). The results must be understood as a comparison between the status quo and a result in which the scenario, *ceteris paribus*, has been achieved. Results from MRIO scenarios are first-order impacts, devoid of the effects of assumptions about substitution elasticities, utility and profit maximization, price equilibrium, etc. Some key assumptions include:

- Prices are not endogenized, that is, relative prices between products and countries do not change. Changes in relative prices resulting from technological change would lead, for example, to changes in the production structure and production locations through substitution or complementary effects.
- All changes implemented in the model are exogenous, which makes it impossible to model systemic rebound effects (i.e. macro-economic price or growth effects).[2]
- Market shares and bilateral trade shares remain constant.

Implementing technological change in an MRIO[3]

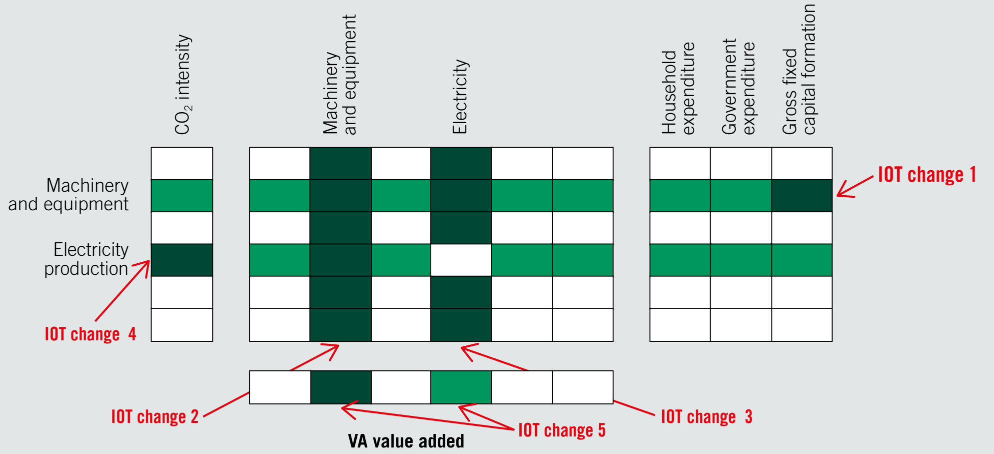
As described by Wiebe (2018), the transition to a green economy requires structural and technological change. Several scenarios in this report involve technological change to a certain extent. For example, electricity generation shifts from fossil fuels to renewables; agriculture changes to conservation or organic agriculture, shifting the sets of inputs required, and in a circular economy metal inputs change from direct manufacture and mining to recycling.

In an input–output framework, both the economic structure and technology are represented as the intermediate input coefficients. But modelling technological change in an economy by changing the input coefficients alone is not sufficient. Wiebe (2018) explains how to consistently model technological change in a forward-looking multiregional input–output model and, to this end, differentiates between five types of changes regarding parts of the input–output system (as shown in figure A2.1):

2. Gillingham et al. (2013) argue that rebound effects are generally small.
3. This section follows the discussion already noted in Wiebe (2018).

Figure A2.1

Changes related to technology diffusion in an environmentally extended input–output framework



Note: As described in Wiebe (2018), wind turbines are produced by the "machinery and equipment" (M&E) industry. Thus an increased diffusion of wind turbines is reflected in a change in the investment in M&E (IOT change 1), changing intermediate input coefficients due to the increased share of wind turbines in the total production of the M&E industry (IOT change 2). Moreover, as more wind turbines are used for electricity production (Elec), less coal and gas is needed, changing the input coefficients of the electricity industry (IOT change 3). This in turn reduces the CO_2 intensity (CO_2int) of the electricity industry.

Source: Based on Wiebe, 2018.

1. Gross fixed capital formation
2. Input coefficients for technology production
3. Input coefficients for technology use
4. Emission intensity of production (or any other relevant environmental or socio-economic extension)
5. Value added shares, including compensation of employees.

In Wiebe (2018), these changes are explained using the example of increasing electricity production through wind turbines. The goal is for more electricity to be produced by wind relative to the status quo in the current input–output system. The first step in the process is to invest in more wind parks. This is shown in figure A2.1 as input–output table (IOT) change 1, a change in gross fixed capital formation (GFCF). For the sake of simplicity, the arrow in the figure points only to the machinery and equipment industry, which produces wind turbines. But it is important to remember that the wind turbines need to be planned, which requires services from "other business activities", and to be connected to the grid, which requires products from the "electrical machinery and apparatus" industry, to mention the other two most important industries associated with an investment in a new wind park.

Once the investment is made, the technology (wind turbines) needs to be produced. As more wind turbines are produced relative to other products in the machinery and equipment industry, the structure of intermediate inputs into the "machinery and equipment" industry changes (see IOT change 2 in figure A2.1). Once the technology is available and installed, it can be used. That is, electricity is produced with more wind relative to other energy carriers. The most obvious difference in the input structure of the electricity industry is the reduced use of fossil energy carriers. The change in the composition of inputs into electricity production is labelled "IOT change 3" in figure A2.1. If, as in Exiobase, the electricity industries are already modelled by energy carrier, the switch to more wind electricity is simply modelled through increased intermediate and final demand for electricity generated by wind.

Relative to the changes in the input structure of the technology-producing industry (IOT change 2) and the technology-using industry (IOT change 3), the corresponding emission intensities of these industries need to be modified (IOT change 4 in figure A2.1). That is, if less coal input is used, the emission intensity of production of that industry decreases. This is the case for IOTs with only one aggregated electricity industry, such as the MRIO systems GRAM (Wiebe et al., 2012), the OECD ICIO (Wiebe and Yamano, 2016) or WIOD (Timmer et al., 2014). If the wind electricity industry is an individual industry in the input–output table, as in Exiobase (Stadler et al., 2018), a change in the emission coefficient of the wind industry is not necessary. The emission intensity of total electricity production will change according to the composition of electricity production.

It should be noted that the focus in Wiebe (2018) is on emissions. However, the extended input–output methodology is also applicable to any other kind of environmental and socio-economic extensions. When estimating the impact of other environmental or socio-economic factors, the corresponding stressors (e.g. the number of employees per unit of output) need to be changed as well. In other words, if it is assumed that more labour is necessary for the maintenance of renewable energy production and we model an increased VA share for compensation of employees, it is necessary to consider an increase in the number of employees or a productivity increase that is reflected in increased wages. If the compensation of employees rises but the number of employees remains the same, employees earn a higher average wage.

This leads directly to IOT change 5, changes in the value added shares, i.e. taxes and subsidies, compensation of employees and consumption of fixed capital. These value added shares may need to be updated for both the technology-producing industry and the technology-using industry. This is done using the same approach as updating the intermediate input coefficients: $\boldsymbol{va}_{j,t} = (1 - s_t \boldsymbol{va}_{M\&E} + s_t \boldsymbol{va}_{WIND})$ for the machinery and equipment industry, where s_t reflects the share of wind turbine production in total production of the machinery and equipment industry in a given year t.

In the case described here, neither the technology used nor the technology-producing industries are explicit for the technology. In other cases, referred to briefly above in the case of the electricity industry in Exiobase, different levels of information are available for the technology-producing and technology-using industries. To model the changes in the electricity technology-producing industry, input coefficient vectors for renewable electricity technologies are available from Lehr et al. (2011). For other scenarios (e.g. organic and conservation agriculture), information is available only for selected input coefficients (e.g. fertilizer, energy, machinery and employment inputs). In that case, the entire input structure of the agriculture industries was not changed, but only those coefficients for which information is available. Naturally, any combination of levels of information on technology production and use can be available. This description therefore provides some examples of how to deal with levels of information availability.

The transition to a green economy affects several industries at the same time in different ways, including changes in individual intermediate input coefficients, capital formation, intermediate and final demand, value added shares and emission/employment intensities. When implementing these individual changes, it is necessary to bear in mind that the changes need to be consistent. If the use of fossil fuels as intermediate inputs in an industry is reduced, the corresponding emission coefficient needs to be reduced as well. If a new technology is used, it needs to be produced (capital needs to be invested). If one input coefficient of an industry is increased another input coefficient or value added share needs to be decreased or vice versa, because the sum of input coefficients plus value added component shares always add up to 1.

Scenario-specific details and assumptions

This section provides details on the specific technological changes and changes to final demand associated with each of the six scenarios evaluated in the report.

The transition in the energy sector

This scenario implements the energy pathways laid out by two of the International Energy Agency (IEA) Energy Technology Perspectives (IEA, 2015): the 2°C scenario and the 6°C scenario. It implements the IEA scenarios in the MRIO as laid out for each country and industry up to 2030, considering the changes in electricity generation and heat production, industry, transport and construction. It considers substitution of fossil fuel-based energy by renewables and improvements in energy efficiency. IEA (2015) provides more details on each of these two pathways. In the 2°C scenario, energy demands from industry in 2030 fall by 20 per cent and the resulting energy needs are met with greater reliance on biomass and waste, as opposed to electricity or other fossil fuel-based energy sources.

Inherent in this scenario is an advanced switch to electric vehicles and greater energy efficiency of buildings. These changes reflect scenarios for green transport and green construction and complement the transformation of the energy sector with changes in employment resulting from a shift from internal combustion engines to electric vehicles and the employment demand to increase the energy efficiency of existing buildings. UBS Research (2017) provides projections for the sales of electric vehicles and the change in inputs compared to internal combustion vehicles. It also provides details on the employment and input structure related to efforts to increase the energy efficiency of buildings. Under this scenario, all savings from energy efficiency in the IEA 2°C scenario are invested in the construction sector to retrofit buildings and achieve greater efficiency.

The 2°C scenario is used as a model for greening the energy sector through changes in electricity generation, industry energy demand, transport and construction. The 6°C scenario is used as a model for the business-as-usual scenario in this and all other scenarios discussed in the report.

The transition in agriculture: Organic and conservation agriculture

A comprehensive literature review resulted in 264 coefficients that compare the crop, livestock and country-specific yields from organic agriculture and conventional agriculture. These coefficients also include the energy, employment, crop protection, machinery and fertilizer requirements for each mode of production for each of Exiobase's agriculture sub-industries (cultivation of rice, wheat, cereals n.e.c., oil seeds, sugar cane/beet, plant fiber and crops n.e.c.; cattle, pig and poultry farming; meat animals n.e.c., animal products n.e.c., raw milk and wool/silk production).

The other coefficients are imputed by combining them with World Development Indicators (World Bank, 2017) for GDP per capita and the share of labour in agriculture and the data of Lowder, Skoet and Raney (2016) on the average size per farm. A first round of 50 imputations are applied out for fertilizers, crop protection and yield. An independent set of 50 imputations are applied for employment, and another independent set of 50 imputations for energy. Second, all 50 imputations are averaged out and extreme values are trimmed. The whole table is imputed again 50 times, considering each input and yield as a categorical variable in the imputation. This imputation is then averaged once again and extreme values trimmed. Table A2.2 presents the country-to-country averages for each input and agricultural sub-industry. The full table includes specific estimates for each country and region in Exiobase.

The animal products n.e.c. and wool sub-industries could not be imputed due to the complete lack of coefficients in the literature. The animal products n.e.c. sub-industry is imputed as an average for the different livestock sub-industries. The wool sub-industry is imputed as the average of all agriculture sub-industries.

Synthetic fertilizers and herbicides are substituted by organic alternatives. In Exiobase, these are modelled through animal manure and composting and biotechnology services (research and development).

In addition, a comprehensive literature review resulted in 77 coefficients that compare the crop- and country-specific yields of conservation agriculture and conventional agriculture. These coefficients also include the energy, employment, crop protection and fertilizer requirements for each mode of production for each of Exiobase's agriculture crop-based sub-industries (cultivation of rice, wheat, cereals n.e.c., oil seed, sugar cane/beets, plant fiber and crops n.e.c.; cattle, pig and poultry farming; animal meat n.e.c., animal products n.e.c., raw milk and wool/silk production).

In view of the scarcity of coefficients in the literature, it was not possible to use multiple imputation reliably to complete the table of coefficients. Nor was it possible to consider reliably estimates by agricultural sub-industry. The average of the coefficients for crops is used for all countries and regions. This is a tenable assumption, as conservation agriculture is equally cost-effective (from a labour viewpoint, for example) in developing, emerging and developed countries alike. As conservation agriculture deals only with crop-based agriculture, coefficients for the cattle, pig and poultry farming, animal meat n.e.c., animal products n.e.c., raw milk and wool/silk production industries are set as equal to conventional agriculture. Table A2.3 presents the coefficients for each input and agricultural sub-industry.

The scenario explores the employment structure of the economy if organic agriculture were to grow to reach 30 per cent of agricultural output in developed (i.e. high-income) countries and if conservation agriculture were to grow to represent 30 per cent of agricultural output in developing (i.e. low- and middle-income) countries in 2030. FiBL and IFOAM provide the baseline figures for the size of the organic agriculture sector in each country in 2014 (Willer and Lernoud, 2017). FAOStat provides the baseline figures for the size of conservation agriculture in each country in 2014 under the indicator "Area of arable land and permanent crops under protective cover" (FAO, 2017). Each agricultural sub-industry is assumed to have the same share of organic and conservation agriculture within each country. This scenario is compared to a business-as-usual scenario defined by the IEA 6°C scenario.

Table A2.2

Input and yield ratios comparing organic and conventional agriculture

	Crop protection	Employment	Energy	Fertilizer	Machinery	Yield
Rice	0.90	1.50	0.35	0.96	0.92	0.84
Wheat	0.86	1.99	0.78	0.90	0.85	0.74
Cereals n.e.c.	0.59	1.04	0.60	0.59	0.67	0.79
Vegetable and fruit	0.61	1.35	1.02	0.57	0.67	0.82
Oil seeds	0.80	1.62	0.26	0.86	0.85	0.81
Sugar	0.78	0.37	0.78	0.82	0.85	0.86
Plant fibre	0.62	1.24	0.78	0.59	0.61	0.64
Crops n.e.c.	0.51	1.40	0.79	0.51	0.59	0.69
Cattle	0.67	1.74	0.81	0.67	0.77	0.89
Pig	0.95	1.33	0.74	0.95	0.95	0.95
Poultry	0.82	1.04	0.36	0.82	0.81	0.81
Meat n.e.c.	0.51	0.75	2.11	0.47	0.55	0.70
Animal n.e.c.	0.73	1.22	1.00	0.72	0.77	0.83
Milk	0.69	0.95	0.74	0.65	0.73	0.84
Wool	0.72	1.51	0.78	0.72	0.76	0.81

Notes: Each value denotes the country-to-country average of coefficients used in the scenarios. For example, it shows that, across all countries and regions in Exiobase, organic agriculture uses 0.90 of the crop protection inputs that conventional agriculture uses. To compute these averages, each country or region is weighted equally.

Source: ILO calculations based on literature review yielding 264 coefficients.

Table A2.3

Input and yield ratios comparing conservation and conventional agriculture

	Crop-based agriculture	Animal-based agriculture
Crop protection	1.20	1.00
Employment	0.76	1.00
Energy	0.60	1.00
Fertilizer	1.01	1.00
Yield	1.21	1.00

Notes: Each value denotes the coefficients used in the scenarios. For example, it shows that, across all countries and regions in Exiobase, conservation agriculture uses 1.20 of the crop protection inputs that conventional agriculture uses.

Source: ILO calculations based on literature review yielding 77 coefficients.

The circular economy

This scenario explores the employment impact of a sustained 5 per cent annual increase in recycling rates for plastics, glass, pulp, metals and minerals across countries, replacing the direct extraction of the primary resources for these products. This scenario also models growth in the service economy which, through rental and repair services, reduces the ownership and replacement of goods. The scenario considers a 1 per cent annual growth in the services sector, replacing the corresponding demand for the ownership and replacement of goods. It is compared with a business-as-usual scenario, as defined by the IEA 6°C scenario.

2. THE ECONOMIC DEBATE ON CLIMATE CHANGE: EMISSIONS, GROWTH AND EMPLOYMENT

This section provides a brief explanation of three key features of the economic debate on climate change. First, it reviews the range of recommendations for GHG emissions targets and reasons for the divergence in opinions between economists and climatologists. Second, it critically assesses the core assumptions underpinning the widely used Integrated Assessment Models, which forecast the costs of climate change and abatement policy. Third, it discusses proposals for emission-trading schemes as instruments to implement the GHG emissions reduction targets.

Emissions reduction targets

An appropriate policy response to climate change consists of two steps: first, identifying a target for the stock of atmospheric CO_2 compatible with climate stabilization, and, second, defining the legal instruments (including incentives, taxes and other regulatory provisions) that will lead to the necessary reduction in emissions.

The Stern Review (Stern, 2007), which highlights the relevance of GHG concentration targets to economic policy discussions, is the best-known example of the first step. Stern (2007) set the target at 550 ppm CO_2eq (a level at which 0.055 per cent of the atmosphere would be occupied by CO_2) (see table A2.4). This recommendation attracted criticism from both climatologists and economists. Many climatologists argued that Stern's target is too lenient and that 385 ppm CO_2eq would be an appropriate target. Accordingly, they called for immediate divestment from fossil fuels and for investment in renewable resources (Hare, 2009; Meinshausen et al., 2009; IPCC, 2014). Some economists, on the other hand, argued that Stern's target is too aggressive as its short-term impact would be to destabilize the global economy. Their consensus target has been much higher, fixed at a level of at least 650 ppm CO_2eq (Nordhaus, 2007; Dasgupta, 2007). Moreover, they have insisted that this level should be achieved gradually, as if over a "policy ramp".

Despite subsequent updates of these studies and of climate change projections (IPCC, 2013), the terms of the policy discussion have effectively remained unchanged. In fact, while better data can certainly contribute to improving our understanding of climate change, more recent data do not always help. In the study of climate processes, high-frequency data can in fact obfuscate long-term trends (Ackerman, 2017).

The conflict among experts' positions highlights the importance of clarifying subjective judgments about acceptable risk. As shown in table A2.4, the risks of overshooting the 2°C threshold associated with each target are very different. According to Hare and Meinshausen (2004) and Meinshausen (2005), the consensus target for mainstream economists is associated with a risk higher than 90 per cent of surpassing the 2°C threshold. With the Stern Review's target, the probability of surpassing the 2°C threshold is still much higher than the probability of remaining below it. As such, the two highest

Table A2.4

Differences in GHC emission target between experts

	GHG emission target (ppm CO_2eq)	Risk of exceeding 2°C (%)	Price of carbon (US$/t CO_2)	Discount rate (%, annual)
Nordhaus (2008)	650	>90	217	1.5
Stern (2007), IEA (2008), Markandya (2009)	550	85	420	0.1
IPCC (2007), UNDP (2007)	450	50	623*	Multiple
Hansen at al. (2008), Hare (2009), Meinhausen et al. (2009)	385	20	700	–

** author's linear extrapolation*

Source: Storm, 2017.

proposed targets listed in table A2.4 can be interpreted as "de-stabilization targets", since both are likely to create a change in climate, making it permanently unstable.

The more stringent targets proposed by international organizations (IPCC, 2007; UNDP, 2007; IEA, 2008) and by climatologists are associated with higher probabilities that the world's temperature will remain under the 2°C threshold rather than exceed it. However, the most stringent target is still associated with a 20 per cent risk of overshooting, far from offering any certainty about the future of climate stability. A negligible climate risk would require even larger reductions in the stock of GHGs.

The cost of climate change vs the cost of stopping it

Certain economists have proposed the least stringent emission reduction targets because they are primarily concerned with the consequences of emissions reduction for the economy in the short term. With no immediate change in prevailing technology, it is argued that reducing emissions may require slowing down economic growth and job creation. Slower growth and less dynamic labour markets are in turn likely to exacerbate distributive conflicts. However, these effects are largely dependent on assumptions concerning the level of investments in cleaner energy and the promotion of green jobs. As argued in Chapter 2, a new, economically viable source of clean energy would break this link, decoupling economic growth from GHG emissions. However, developing such technology and scaling it up for global availability requires investments and risk-bearing beyond the capacity of the corporate sector alone. In this light, a brief critique of the assumptions underpinning economic modelling of climate change is set out below.

Common economic analyses take into account the costs of both climate change and mitigation policy generally in terms of GDP and employment. Since the costs considered occur over a long period (100 years or more) and affect the economy in direct and indirect ways, they are summarized using models that, based on a series of assumptions, reduce them to comparable quantities. These "Integrated Assessment Models" (IAMs) are computerized models of the economy that link aggregate economic growth with simplified climate dynamics in an effort to understand and forecast the impact of GHGs and GHG reduction on growth and employment. The main IAMs are MERGE (Manne, Mendelsohn and Richels, 1995), PAGE (Hope, 2011), FUND (Anthoff and Toll, 2012) and RICE/DICE (Nordhaus and Sztorc, 2013).

Recent research has pointed out that IAMs generally include problematic assumptions that in fact lead them to underestimate both the probability of catastrophic climate change and the costs of associated social and economic damage. The key problematic assumptions concern the climate damage function and climate risk, the anticipated path of economic growth, and the mechanisms of economic adjustment, generally based on assuming full employment at all times (Ackerman, 2017; Ackerman and Finlayson, 2006; Mastrandrea, 2010; Weitzman, 2009 and 2013).

For example, the climate damage function incorporated into most IAMs relies on two questionable claims: first, that future damages and well-being weigh less than current ones in today's decisions, and, second, that the climate-related events that cause the damage follow a regular and predictable schedule.

The first assumption implies that future generations matter less than living generations in today's decision-making. This may make sense when modelling small costs expected to occur far into the future, but it is not appropriate when faced with the possibility of catastrophic climate change. Once a discount rate is applied, finite costs and incomes that are projected far enough into the future may not affect today's decisions at all.[4] However, this is not appropriate for modelling infinitely large values in the future, such as those that would arise from catastrophic climate change, which would disrupt many critical forms of economic (and human) activity. The present discounted value of such an infinitely large loss is infinitely large. However, IAMs only consider the average costs and incomes arising from future events, thereby disregarding the very high costs of rare events such as natural disasters. In practice, IAMs input a positive social discount rate, a parameter that reduces the present value of future incomes and

4. Two approaches to discounting are mainly used: a prescriptive approach defining the rates of discount that should be applied, and a descriptive approach based on the rates that people's choice of saving and investment reveal. While the former approach leads to relatively low rates of discount (2–3 per cent in real terms) the latter leads to relatively higher rates (at least 6 per cent and, in some cases, much higher rates).

costs. For example, with an annual discount rate of 1.5 per cent, a US$ 1,000 cost incurred 30 years ago is worth less than US$ 650 today. In general, much of the difference between the Stern Review's conclusions and those of many economists is due to the choice of a lower discount rate in the former.[5]

Concerning the second assumption, namely that climate-related events follow a regular and predicted schedule, the implication is that people can make rational decisions based on the observed probabilities of actual events, relying on average costs and incomes. But new thinking in behavioural economics suggests that this approach to risk is incompatible with actual behaviour. Recent research demonstrates that more realistic assumptions on risk aversion (assumptions that consider the cost of rare events, a better balance between immediate costs and future risks and the distraction of short-term fluctuations), which are closer to applications of the precautionary principle, would lead to more realistic models of climate change (Gerst, Howarth and Borsuk, 2010; Ackerman et al., 2013; Brekke and Johannson-Stenman, 2008). In other words, a clearer explanation of what is at stake and how real the danger is would lead people to give a higher priority to climate policy.

These limitations of commonly used models point to the fact that the usual frame of cost–benefit analysis is not an appropriate approach for informing climate policy. First, cost–benefit analysis is not suitable when human life is at stake in such large numbers, e.g. people at risk of losing their lives because of climate disasters. In the end, policy formulation must be both economically and ethically sound. For example, a cost–benefit analysis is not permitted in the context of the United States Occupational Safety and Health Act of 1970, precisely because the cost of regulation should never outweigh the benefits of lives saved. Second, it is not suitable when the costs involved are exceedingly high. In principle, no matter how high the cost of abatement policy, it makes sense to bear it because once the climate system is compromised, it cannot be restored. An implicit assumption in cost–benefit analysis is that if the cost of reducing the use of a resource is too high, then the resource ought to be exhausted first prior to sourcing an alternative on the market. The problem is that if the "climate resource" is compromised then the option of alternative sourcing on the market is not available. Third, the cost–benefit approach is inappropriate because the costs are determined by possible catastrophic events, which cannot be predicted accurately, and because "there is no single formula for risk aversion that is relevant for evaluation of policy options across the board" (Ackerman, 2017, p. 138). The overall lesson from the recent critical analyses is that commonly used IAMs understate the importance of catastrophic climate events, rendering their results and policy recommendations unreliable.

Carbon markets and other solutions

An obvious solution to climate change, increasingly adopted in cities and individual countries around the world, is to ban or regulate the activities responsible for it, for example by imposing emission standards on vehicles and heating systems of buildings, or by phasing out certain types of fossil fuels. However, the international consensus is largely informed by an alternative economic framework that seeks to integrate, and thereby diminish, the costs of climate change within a competitive market function. The framework relies on the idea of "negative externality", namely that a phenomenon, e.g. climate change, can be conceived of as a byproduct of some people's behaviour that affects everyone else. Because those who emit carbon dioxide share the cost with the rest of the world (while generally appropriating all the benefits of their activity), they can effectively consider a portion of their resource-related costs as external to their activities. The recommended solution, therefore, is to force those responsible for GHG emissions to "internalize" the full cost of their activity by making sure, with taxes or tradable permits, that they pay the entire social cost of carbon rather than a fraction of it or none at all.

Of the two ways to bring the market price of carbon closer to its social cost, taxes are generally overlooked both because they are unpopular with influential constituencies and because they do not offer any certainty about what level of carbon emissions will be legitimized. Provided carbon taxes are paid, a company or industry can in principle produce any amount of GHGs. By contrast, a cap-and-trade system – in which emissions are capped at a given level, the related permit assigned to market participants and eventually traded on an established market – provides greater certainty about the level of emissions produced. Also, a carbon-trading system would normally determine a market price for

5. Beyond the technicalities of economic calculations, discounting raises ethical questions because the future generations whose well-being is overlooked in today's decisions are also the least responsible for the climate system and the climate-affected economy they will operate in. Unsurprisingly, many experts argue for abandoning discounting altogether in the discussions on climate policy (Arrow, 2007; Ackerman and Stanton, 2008; Weitzman, 2007 and 2009).

emissions close to their social cost, creating an incentive for businesses to develop cleaner and necessarily cheaper sources of energy.

In practice, however, things play out differently, as the experiences of the Kyoto Protocol mechanisms and the European Union Emission Trading System have shown: *actual emission trading systems do not lead to the desired reductions in emissions*. Five reasons impair carbon markets' ability to deliver the desired outcomes (Storm, 2017):

1. Volatility in carbon markets, in part caused by speculative behaviour, leads to a lock-in of fossil fuel technology. In fact, for businesses to invest in alternative energy sources, they should expect a permanently high price of carbon.
2. The required measurement and enforcement apparatus is larger than that required by direct regulation. This is particularly true for carbon offsets – investments meant to absorb GHGs from the atmosphere offsetting emissions elsewhere – envisioned by the Kyoto Protocol.
3. Inherent market failures. Carbon markets would likely suffer from information asymmetries and unenforceable contracts, which would eliminate incentives to invest in alternative energy (Speth, 2008; Stiglitz, 2008).
4. Carbon markets would be efficient only if they determined a universal price for carbon, the same for all uses in all countries (Stiglitz, 2008). This does not happen in current trading systems, which create other external costs that contribute to inequalities. For example, the increase in biofuel production has been linked to increases in food prices (Mitchell, 2008) and the Kyoto Protocol's carbon offsets have been linked to land grabs (Lohmann, 2009).
5. To achieve emissions targets, the price of carbon would have to be very high, with likely harmful consequences on the poorest (Stiglitz, 2008). These could be compensated with appropriate mechanisms but any such solution would have to be clearly designed preemptively.

A reflection of the above difficulties is the difference that currently exists between the market price of carbon (which between 2001 and 2017 remained below US$10 per tonne of CO_2eq) and the prices that would be required for emissions to respect the various proposed targets (table A2.4). The least stringent target would require a price of US$217, more than 15 times the market price. The price associated with climatologists' more stringent target would be in the order of US$700, almost 50 times the market price (Storm, 2017).

For all these reasons, carbon markets are not likely to function in practice in the way they do in economic models. Given the reality of carbon markets and the complications related to their distributive effects, direct regulation may offer a more effective and administratively simpler alternative. This insight is picked up in at least two different approaches to economic policy: the Green New Deal and the "limits to growth" approach.

Proponents of the Green New Deal or "Big Push toward a Zero-Carbon Economy" argue that the climate change "negative externality" can be more effectively eliminated with a global carbon tax and that the tax should be accompanied both by appropriate regulation to make sure that emissions targets are respected and by policies that strengthen social protection systems to correct any negative distributive consequences of emissions reduction (Grubb, Hourcade and Neuhoff, 2014, Herman, 2015, Pollin et al., 2014). They also assert, based on recent research on the economics of innovation (Mazzucato, 2013; Mazzucato and Perez, 2014), that enforcing a carbon price close to the real social cost of carbon is not enough to mobilize the resources necessary to develop alternative energy sources. Since the risks associated with these investments are too large for the limited appetite for risk of private banks and businesses, governments would have to step in – using at least the revenues from carbon taxes – and actively promote the required R&D projects (Storm, 2017). The absence of financial markets and a discussion on financing from IAMs lends support to this view.

The "limits to growth" approach is based on the view that all economies face both ecological and social limits. Its proponents argue that market and government institutions must be assessed in light of their ability to support growth paths that do not exceed the carrying capacity of the ecosystems (with their resource use) or of society (by causing unsustainable inequalities). While this approach is compatible with all the proposals of the Green New Deal in terms of carbon taxes and innovation financing, it differs in that it maintains that formal redistribution systems (such as taxation and social protection systems) are not always able to redress market inequalities (Klein, 2014; Vira, 2015). Consequently, institutions should be assessed and possibly amended in order to ensure that they do not produce unsustainable inequalities.

3. EMPLOYERS' ROLE IN THE TRANSITION

The analysis of the role of employers in the transition draws on the Carbon Disclosure Project and FactSet, two firm-specific data sets.

The Carbon Disclosure Project (CDP) is a voluntary survey in which companies disclose their GHG emissions and give their opinions and experience on policies and their specific efforts and targets to mitigate emissions (see, for example, CDP, 2016, which provides descriptive results for the complete sample). CDP covers firms from the consumer staples, consumer discretionary, energy, financial, health care, industrial, IT, materials, telecommunications and utilities sectors. In 2015, a total of 1,997 firms responded to the questionnaire. In 2010, this figure was 1,799 companies.

CDP questionnaires and data are available through www.cdp.net.

FactSet provides historical financial information at the firm level, including information on sales and employment for 2010 and 2015. More information on it is available through www.factset.com.

FactSet contains information on employment and sales for 760 of all firms with public CDP information for 2010 and 2015.

The descriptive analysis of the role of employers in the transition focuses on these 760 firms with complete information on employment, sales and GHG emissions. Tables A2.5 to A2.7 list the characteristics of these companies by size, sector and region.

Table A2.5

Size of firms available in FactSet with CDP data for both 2010 and 2015 (percentages)

Number of employees	2010	2015
0–1,000	4.9	4.0
1,000–10,000	27.0	25.5
10,000–50,000	40.0	41.8
50,000–100,0000	14.2	14.2
More than 100,000	14.0	14.5
Total	*100.0*	*100.0*
N	*760*	*760*

Notes: Only firms with data in CDP for 2010 and 2015 and with data in FactSet are considered. Percentages may not add up to 100 due to rounding.

Table A2.6

Sectoral distribution of firms in FactSet with CDP data for both 2010 and 2015 (percentages)

NACE code	Sector	Percentage
A	Agriculture, forestry and fishing	0.0
B	Mining and quarrying	8.4
C	Manufacturing	40.1
D, E	Utilities (electricity, gas, steam and air conditioning supply)	6.3
F	Construction	4.5
G	Wholesale and retail trade, repair of motor vehicles and motorcycles	4.6
H, J	Transport, storage, information and communication	12.8
I	Accommodation and food service activities	3.7
K	Financial and insurance activities	16.6
L, M, N	Real estate, business and administration	2.2
Q	Health and social work	0.8
Total		*100.0*
N		*760*

Notes: Only firms with data in CDP for 2010 and 2015 and with data in FactSet are considered. Percentages may not add up to 100 due to rounding.

Table A2.7

Regional distribution of firms in FactSet with CDP data for both 2010 and 2015 (percentages)

Region	Percentage
Africa	4.6
Americas	33.2
Arab States	0.0
Asia and the Pacific	17.0
Europe	45.2
Total	*100.0*
N	*760*

Notes: Only firms with data in CDP for 2010 and 2015 and with data in FactSet are considered. Percentages may not add up to 100 due to rounding.

Appendix 3

LINKS BETWEEN MULTINATIONAL ENVIRONMENTAL AGREEMENTS (MEAs) AND INTERNATIONAL LABOUR STANDARDS

Year	Agreement	No. parties	Relevant treaty provision	Relevant ILS	No. of ILS[1]
1982	United Nations Convention on the Law of the Sea, 1982 (UNCLOS)	168	• Obligation to ensure safety at sea with regard to labour conditions and the training of crews, taking into account the applicable international instruments (Article 94).	**MLC, 2006; Also C133, C134, C146, C147, C163, C164, C165, C166, C178, C179, C180, C185, P147, R48, R49, R75, R78, R139, R140, R141, R142, R173, R174.**	24
1992	Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992	10	• Shipboard working conditions (Annex IV).	**MLC, 2006; Also C133, C134, C146, C147, C163, C164, C165, C166, C178, C179, C180, C185.**	13
1994	Convention on Nuclear Safety, 1994	80	• Protection of workers from radiation exposure, to be kept "as low as reasonably achievable" and not exceed prescribed national dose limits (Article 15).	**C115, R114, C155, P155.**	4
1994	United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa, 1994	197	• Increased income and employment opportunities, especially for vulnerable members of the community (Annex I, Article 8).	**Core labour standards: C87, C98, C29, C105, C138, C182, C100, C111, C122, C168, R169.**	11
1995	Agreement for the Implementation of the Provisions of the UNCLOS relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, 1995	89	• Recognition of special needs of vulnerable groups in terms of enhancing their income generation and employment opportunities (access to fisheries by subsistence, small-scale and artisanal fishers and women fishworkers) (Article 24).	**C111, C122, C168, C169, R104. See also Declaration on Fundamental Principles and Rights at Work**	5
1996	International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea, 1996*	1	• Application of the Convention without prejudice to the national applicable law relating to workers' compensation or social security schemes (Article 4).	**R181, R194.**	1
1997	Convention on Supplementary Compensation for Nuclear Damage, 1997	19	• Prevalence of national schemes of workers' compensation (occupational disease compensation), where they exist (Annex, Article 8).	**R181, R194.**	2
1997	Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 1997	71	• Radiation exposure of workers to be kept as low as reasonably achievable (Article 24).	**C155, P155, C174, C148, C139, C115, R114, R156.**	8
1998	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Heavy Metals, 1998	34	• The dust from all pyrometallurgical production should be recycled in-plant or off-site, while protecting occupational health (Annex III).	**C155, P155, C148, C139, R156.**	5
1998	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, 1998	160	• Protection of workers against the potentially harmful impact of certain hazardous chemicals and pesticides in international trade (Preamble); • Notification of regulatory action includes information on the summary of hazards and risks presented by chemicals to workers and the expected effect of the regulatory action (Annex I).	**C155, P155, C148, C139, C170, C184, C184, R156, R177, R192.**	9
2001	Stockholm Convention on Persistent Organic Pollutants (POPs), 2001	181	• Training of workers on persistent organic pollutants (Article 10); • Best available techniques to reduce chemicals as provided for by the Convention should include consideration of the need to ensure occupational health and safety at workplaces (Annex C, Part V(B)).	**C155, P155, C142, R195.**	4

Year	Agreement	No. parties	Relevant treaty provision	Relevant ILS	No. of ILS[1]
2003	Kiev Protocol on Pollutant Release and Transfer Registers to the Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, 2003	**36**	• Whistle-blower protection at work (Article 3).	**R094, R129, R130.**	**3**
2006	International Tropical Timber Agreement, 2006	**73**	• Need to improve working conditions in the forest sector taking into account ILO Conventions (Preamble); • Increasing employment opportunities (Article 1).	**C122, C169, C184, R104, R169, R192.**	**6**
2009	Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009*	**5**	• Occupational safety and health of workers involved in ship recycling (Preamble); • Obligation to establish management systems, procedures and techniques which do not pose health risks to the workers concerned (Regulation 17); • Policy to ensure worker safety (Regulation 18); • Identification of roles and responsibilities of employers and workers when conducting ship recycling (Regulation 18); • Devising a programme to provide appropriate information and training of workers (Regulation 18); • A system for reporting discharges, emissions, incidents and accidents causing damage or with the potential to cause damage to worker safety (Regulation 18); • A system for reporting occupational diseases, accidents, injuries and other adverse effects on workers' safety (Regulation 18); and a system to prevent accidents, occupational diseases and injuries or other adverse effects on worker safety and health (Regulation 19); • Appropriate training and equipment of workers on safe and environmentally sound management of hazardous materials (Regulation 20); • Handling of waste in a manner that does not pose a risk to the workers (Regulation 20); • Emergency preparedness and response information and training for all workers of the ship recycling facility (Regulation 21); • Worker safety (including the use of personal protective equipment) and training covering all workers, including contractor personnel and employees (Regulation 22); • A system of reporting incidents, accidents, occupational diseases and chronic effects (Regulation 23).	**C155, P155, C174, C148, C139, C115, C162, C170, C144, C142, R114.**	**11**
2009	Statute of the International Renewable Energy Agency, 2009	**143**	• Aimed at fostering the positive impact that renewable energy technologies can have on stimulating sustainable economic growth and creating employment (Preamble).	**Comment: general hortatory principle, outlining one of the intentions of the parties.**	
2013	Minamata Convention on Mercury, 2013	**43**	• Promotion of educational and preventive programmes on occupational exposure to mercury and mercury compounds (Article 16); • Cooperation and exchange of information with the ILO (Article 16); • Reduction, where feasible elimination of the use of mercury and mercury compounds in artisanal and small-scale gold mining (Article 7 and Annex C).	**C155, P155, C148, C139, R156.**	**4**
2015	Regulations concerning the International Carriage of Dangerous Goods by Rail	**n.a.**	• Training of workers in radiation protection and precautions to restrict their occupational exposure (Chapter 1.7).	**C155, P155, C148, C139, C115, R114, R156.**	**7**
2015	Paris Agreement under the United Nations Framework Convention on Climate Change, 2015	**144**	• Consideration of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities (Preamble).	**Comment: ILS broadly form part of the context of the Paris Agreement.**	**Various ILO Conventions**

*Note: * not yet in force. C = Convention; R = Recommendation; P = Protocol.*

1. Number of related instruments or number of standard-setting areas. Numbers of ILO references are approximate, as they reflect only very direct relevance.

Appendix 4

Chapter 5 provides a snapshot of the current green employment trends and skills development in 27 country studies on skills for green jobs commissioned to national experts by the ILO in partnership with Cedefop. This appendix provides background information on the national studies on skills for green jobs. All studies follow the same methodology to ensure comparability of findings.

Selection of the countries covered in the national skills studies

Of the 27 country studies, 21 had already been analysed by the ILO and Cedefop in the report *Skills for green jobs: A global view* (Strietska-Ilina et al., 2011). Six more countries were chosen in collaboration with ILO technical departments and field offices, with a view to reflecting the various environmental and decent work challenges.[1] National experts (institutions or individuals) were selected to carry out each study on the basis of their expertise in skills identification and development and their demonstrated knowledge and understanding of environmental and climate change issues. Whenever possible, the same experts were selected as for the 2011 study. Cedefop was responsible for conducting the country studies on the six European countries.

Key research questions addressed in the country studies

- Which main challenges in the structural transformation deriving from the key drivers of change (green policies, programmes and regulations, green technologies, climate change and environmental degradation, market forces and globalization, etc.) have you observed?
- What is the impact on employment and related occupational skills, as well as broader technical and soft skills needs?
- Are skills development policies and environmental sustainability/climate change policies coherent? How is the coordination of policy formulation and implementation ensured? Does policy planning involve the ILO tripartite constituents?
- What policies, programmes, regulations and measures are being implemented to adjust the competencies of the potential and current workforce, retrain workers and upgrade skills for jobs in the green economy? (Covering initial and continuing TVET, private sector skills training, workplace learning, active labour market policies, validation of non-formal and informal learning or training.)
- How do green policies, programmes and regulations include gender issues in the development of new green skills?
- How successful have these measures been in narrowing the skills gap to facilitate a smooth and just transition to the low-carbon and green economy? What are the success factors and good practices? What are the main challenges?
- Have the (recently) implemented measures been of more of an ad hoc or a systematic nature?

Methodology for the country studies

Each country study followed the same methodology, which is also the methodology used in the 2011 study, to ensure comparability across the studies, while offering flexibility to adjust to local conditions.

The studies draw on secondary analysis of quantitative data on employment and interviews conducted with representatives from trade unions and employers' organizations, policy-makers at the different levels, human resource development and TVET decision-making bodies, sectoral organizations, public–private initiatives, representatives of companies at the forefront of sustainable development and those actively involved in the implementation of the greening policy agenda, and national statistical offices.

Quality check of the country studies

Each country study benefited from the comments of the network of skills and green jobs specialists in the ILO field offices as a quality check.

1. The 21 countries are: Australia, Bangladesh, Brazil, China, Costa Rica, Denmark, Egypt, Estonia, France, Germany, India, Indonesia, the Republic of Korea, Mali, Philippines, South Africa, Spain, Thailand, Uganda, the United Kingdom and the United States. The six new countries are: Barbados, Guyana, Kyrgyzstan, Mauritius, Montenegro and Tajikistan.

Methodology for analysis

Based on the frameworks for analysing public policies developed by Morestin (2012) and the National Research Council (2010), Chapter 5 adopts the following guiding principles to synthesize the information collected by the country studies and to evaluate skills development policies and programmes for green jobs:

1. Implementation of the policy:
   a. Awareness and acceptability of the role of skills development for a just transition among policy-makers and the general public;
   b. Feasibility of the policy in terms of cost and institutional support;
   c. Adaptability of the policy to changes in skills needs;
   d. Durability and sustainability of the policy.
2. Effects of the policy:
   a. Effectiveness;
   b. Equity and decent work outcomes.

References (Appendices only)

Ackerman, F. 2017. *Worst-case economics: Extreme events in climate and finance* (London, Anthem Press).

—; Finlayson, I.J. 2006. *The economics of inaction on climate change: A sensitivity analysis*, Global Development and Environment Institute, Working Paper No. 06–07 (Tufts University, Medford, MA).

—; Hansen, J.; Kharecha, P.; Sato, M.; Masson-Delmotte, V.; et al. 2013. "Assessing 'dangerous climate change': Required reduction of carbon emissions to protect young people, future generations and nature", in *PLoS One,* Vol. 8, No. 12.

—; Stanton, E.A. 2008. *Climate change and the U.S. economy: The costs of inaction* (Medford, MA, Global Development and Environment Institute at Tufts University).

Anthoff, D.; Tol, R.S.J. 2012. *The climate framework for uncertainty, negotiation and distribution (FUND): Technical description, version 3.6* (Hamburg, Forschungsstelle für Nachhaltige Entwicklung, University of Hamburg).

Arrow, K. 2007. "Global climate change: A challenge to policy", in *Economists' Voice*, June, pp. 1–5.

Arsel, M.; Büscher, B. 2012. "Changes and continuities in neoliberal conservation and market-based environmental policy", in *Development and Change*, Vol. 43, No. 1, pp. 53–78.

Brekke, K.A.; Johansson-Stenman, O. 2008 "The behavioural economics of climate change", in *Oxford Review of Economic Policy*, Vol. 24, No. 2, pp. 280–297.

CDP (Carbon Disclosure Project). 2016. *Out of the starting blocks: Tracking progress on corporate climate action* (London).

Dasgupta, P.S. 2007. "Commentary: The Stern Review's economics of climate change", in *National Institute Economic Review*, Vol. 199, pp. 4–7.

Dunne, J.P.; John, J.G.; Adcroft, A.J.; Griffies, S.M.; Hallberg, R.W.; Shevliakova, E.; Stouffer, R.J.; et al. 2012. "GFDL's ESM2 global coupled climate-carbon earth system models. Part I: Physical formulation and baseline simulation characteristics", in *Journal of Climate*, Vol. 25, No. 19, pp. 6646–6665.

—; John, J.G.; Shevliakova, E.; Stouffer, R.J.; Krasting, J.P.; Malyshev, S.L.; Milly, P.C.D.; et al. 2013. "GFDL's ESM2 global coupled climate-carbon earth system models. Part II: Carbon system formulation and baseline simulation characteristics", in *Journal of Climate*, Vol. 26, No. 7, pp. 2247–2267.

FAO (Food and Agriculture Organization of the United Nations). 2017. *FAOStat: Food and agriculture data* (Rome).

Gerst, M.D.; Howarth, R.B.; Borsuk, M.E. 2010. "Accounting for the risk of extreme outcomes in an integrated assessment of climate change", in *Energy Policy*, Vol. 38, No. 8, pp. 4540–4548.

Gillingham, K.; Kotchen, M.J.; Rapson, D.S.; Wagner, G. 2013. "Energy policy: The rebound effect is overplayed", in *Nature*, Vol. 493, No. 7433, pp. 475–476.

Global Footprint Network. 2016. *National footprint accounts: 2016 edition* (Oakland, CA).

—. 2017. *National footprint accounts: 2017 edition* (Oakland, CA).

Green New Deal Group. 2008. *UK needs new Green Deal to tackle the triple crunch of credit, oil price and climate crises* (London, New Economics Foundation).

—. 2013. *A national plan for the UK. From austerity to the age of the Green New Deal* (London, New Economics Foundation).

Grubb, M.; Hourcade, J.C.; Neuhoff, K. 2014. *Planetary economics. Energy, climate and the three domains of sustainable development* (London, Routledge).

Hansen, J. et al. (2008), "Target Atmospheric CO_2: Where Should Humanity Aim?", *Open Atmospheric Science Journal*, 2, pp. 217-31.

Hare, W.L. 2009. "A safe landing for the climate", in Worldwatch Institute (ed.): *State of the World 2009: Into a warming world* (New York, NY, W.W. Norton & Co), pp. 13–29.

—; Meinshausen, M. 2004. "How much warming are we committed to and how much can be avoided?", in *Climatic Change*, PIK Report No. 93 (Potsdam, Potsdam Institute for Climate Impact Research).

Herman, C. 2015. *Green New Deal and the question of environmental and social justice*, Global Labour University Working Paper, No. 31 (Geneva, ILO).

Hope, C. 2011. *The PAGE09 Integrated Assessment Model: A technical description*, Working Paper Series, No. 4/2011 (Cambridge, Cambridge Judge Business School).

IEA (International Energy Agency). 2008. *World Energy Outlook 2008* (Paris).

—. 2015. *Energy technology perspectives 2017: Mobilising innovation to accelerate climate action* (Paris).

IMF (International Monetary Fund). 2017. *World economic outlook, April 2017: Gaining momentum?* (Washington, DC).

ILO (International Labour Office). 2015. *Key Indicators of the Labour Market 2015,* Ninth edition (Geneva).

IPCC (Intergovernmental Panel on Climate Change). 2007. *Climate Change 2007: Summary for Policy Makers. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (New York, NY, Cambridge University Press).

—. 2013. *Climate Change 2013: The physical science basis* (New York, NY, Cambridge University Press).

—. 2014. *Climate Change 2014: Mitigation of climate change* (New York, NY, Cambridge University Press).

Kjellstrom, T.; Freyberg, C.; Lemke, B.; Otto, M.; Briggs, D. 2017. "Estimating population heat exposure and impacts on working people in conjunction with climate change", in *International Journal of Biometeorology,* Vol. 62, No. 3, pp. 291–306.

—; McMichael, A.J. 2014. "Climate change threats to population health and well-being: The imperative of protective solutions that will last", in *Global Health Action*, Vol. 11, No. 2. pp. 1-9.

Klein, N. 2014. *This changes everything: Capitalism vs the climate* (New York, NY, Simon & Schuster).

Koning, A. de; Huppes, G.; Deetman, S.; Tukker, A. 2016. "Scenarios for a 2 °C world: A trade-linked input-output model with high sector detail", in *Climate Policy*, Vol. 16, No. 3, pp. 301–317.

Lehr, U.; Lutz, C.; Edler, D.; O'Sullivan, M.; Nienhaus, K.; Nitsch, J.; et al. 2011. *Kurz- und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt* (Osnabrück, GWS).

Lohmann, L. 2009. "Climate as Investment", in *Development and Change*, Vol. 40, No. 6, pp. 1063–1083.

—. 2011. "Capital and climate change", in *Development and Change*, Vol. 42, No. 2, pp. 649–668.

Lowder, S.K.; Skoet, J.; Raney, T. 2016. "The number, size, and distribution of farms, smallholder farms, and family farms worldwide", in *World Development*, Vol. 87, pp. 16–29.

Lutz, W.; Butz, W.P.; Samir, K.C. 2014. *World population and human capital in the twenty-first century* (Oxford, New York, OUP).

Manne, A.; Mendelsohn, R.; Richels, R. 1995. "MERGE: A model for evaluating regional and global effects of GHG reduction policies", in *Energy Policy*, Vol. 23, pp. 17–34.

Markandya, A. 2009. "Can climate change be reversed under capitalism?", in *Development and Change*, Vol. 40, No. 6, pp. 1139–1152.

Martin, G.M.; Bellouin, N.; Collins, W.J.; Culverwell, I.D.; Halloran, P.R.; Hardiman, S.C.; Hinton, T.J.; et al. 2011. "The HadGEM2 family of Met Office Unified Model climate configurations", in *Geoscientific Model Development*, Vol. 4, No. 3, pp. 723–757.

Mastrandrea, M.D. 2010. "Representation of climate impacts in integrated assessment models", in J. Gulledge, L.J. Richardson, L. Adkins and S. Seidel (eds): *Assessing the benefits of avoided climate change: Cost-benefit analysis and beyond* (Arlington, VA, Pew Center on Global Climate Change), pp. 85–99.

Mazzucato, M. 2013. *The entrepreneurial state: Debunking public vs. private sector myths* (London, Anthem Press).

—; Perez, C. 2014. *Innovation as growth policy: the challenge for Europe.* Working Paper Series (Brighton, University of Sussex).

Meinshausen, M. 2005. *On the risk of overshooting 2°C.* Paper for the scientific symposium "Avoiding Dangerous Climate Change" (Exeter, UK MetOffice).

—; Meinshausen, N.; Hare, W.; Raper, S.C.B.; Frieler, K.; Knutti, R.; Frame, D.J.; Allen, M.R. 2009. "Greenhouse-gas emission targets for limiting global warming to 2°C", in *Nature*, Vol. 458, No. 7242, pp. 1158–1162.

Miller, R.; Blair, P. 2009. "Foundations of input-output analysis", in *Input-output analysis: Foundations and extensions* (Cambridge, Cambridge University Press).

Mitchell, D. 2008. *A note on rising food prices*, World Bank Policy Research Working Paper, No. 4682 (Washington, DC, World Bank).

Morestin, F. 2012. *A framework for analyzing public policies: Practical guide* (Montreal and Quebec, Centre de collaboration nationale sur les politiques publiques et la santé and Institut national de santé publique).

National Research Council (United States). 2010. *Limiting the magnitude of future climate change* (Washington, DC, National Academies Press).

Nordhaus, W.D. 2007. "A review of the stern review on the economics of climate change", in *Journal of Economic Literature*, Vol. 45, No. 3, pp. 686–702.

—. 2008. *A question of balance. Weighing the options on global warming policies* (New Haven, CT, Yale University Press).

—; Sztorc, P. 2013. *DICE 2013R: Introduction and User's Manual* (Durham, NC, Duke University).

Noy, I. 2014. *A non-monetary global measure of the direct impact of natural disasters* (Geneva, United Nations Office for Disaster Risk Reduction).

Pollin, R.; Garrett-Peltier, H.; Heintz, J.; Hendricks, B. 2014. *Green growth. A US program for controlling climate change and expanding job opportunities* (Washington, DC, Centre for American Progress).

Simas, M.; Golsteijn, L.; Huijbregts, M.; Wood, R.; Herwich, E. 2014. "The 'bad labor' footprint: Quantifying the social impacts of globalization", in *Sustainability*, Vol. 6, No. 11, pp. 7514–7540.

Speth, J.G. 2008. *The bridge at the edge of the world: Capitalism, the environment and crossing from crisis to sustainability* (New Haven, CT, Yale University Press).

Stadler, K.; Wood, R.; Simas, M.; Bulavskaya, T.; de Koning, A.; Kuenen, J.; Acosta-Fernández, J.; et al. 2018. "EXIOBASE 3: Developing a time series of detailed Environmentally Extended Multi-Regional Input-Output tables", in *Journal of Industrial Ecology*, doi:10.1111/jiec.12715.

Stern, N. 2007. *The economics of climate change* (Cambridge, Cambridge University Press).

Stiglitz, J.E. 2008. "Sharing the burden of saving the planet: Global social justice for sustainable development", Keynote speech at the Meeting of the International Economic Association, Istanbul, Turkey (June).

Storm, S. 2009. "Capitalism and climate change: Can the invisible hand adjust the natural thermostat?" in *Development and Change*, Vol. 40, No. 6, pp. 1011–1038.

—. 2017. "How the invisible hand is supposed to adjust the natural thermostat: A guide for the perplexed", in *Science and Engineering Ethics*, Vol. 23, No. 5, pp. 1307–1331.

Strietska-Ilina, O.; Hofmann, C.; Durán Haro, M.; Shinyoung, J. 2011. *Skills for green jobs: A global view: Synthesis report based on 21 country studies* (Geneva and Thessaloniki, ILO and Cedefop).

Timmer, M.P.; Erumban, A.A.; Los, B.; Stehrer, R.; de Vries, G.J. 2014. "Slicing up global value chains", in *Journal of Economic Perspectives*, Vol. 28, No. 2, pp. 99–118.

Tukker, A.; de Koning, A.; Wood, R.; Hawkins, T.; Lutter, S.; Acosta, J.; Cantuche, J.M.R.; et al. 2013. "EXIOPOL: Development and illustrative analyses of a detailed global Mr EE SUT/IOT", in *Economic Systems Research*, Vol. 25, No. 1, pp. 50–70.

UBS Research. 2017. *UBS Evidence Lab electric car teardown: Disruption ahead?* (Zurich).

UNDP (United Nations Development Programme). 2007. *Human development report 2007/8 – Fighting climate change: Human solidarity in a divided world* (New York, NY).

Vira, B. 2015. "Taking natural limits seriously: Implications for development studies and the environment", in *Development and Change*, Vol. 46, No. 4, pp. 762–776.

Weitzman, M.L. 2007. “A review of the Stern Review on the Economics of Climate Change”, in *Journal of Economic Literature*, Vol. 45, No. 3, pp. 703–724.

—. 2009. “On Modelling and Interpreting the Economics of Catastrophic Climate Change”, in *Review of Economics and Statistics*, Vol. 91, No. 1, pp. 1–19.

—. 2013. “Tail-hedge discounting and the social cost of carbon”, in *Journal of Economic Literature*, Vol. 51, No. 3, pp. 873–882.

WHO (World Health Organization). 2013. *WHO methods and data sources for global burden of disease estimates 2000-2011* (Geneva).

Wiebe, K.S. 2016. “The impact of renewable energy diffusion on European consumption-based emissions”, in *Economic Systems Research*, Vol. 28, No. 2, pp. 133–150.

—. 2018. “Global renewable energy diffusion in an input-output framework”, in O. Dejuán, M. Lenzen and M.-Á. Cadarso (eds): *Environmental and economic impacts of decarbonization: Input-output studies on the consequences of the 2015 Paris Agreements* (London, Routledge).

—; Bruckner, M.; Giljum, S.; Lutz, C. 2012. “Calculating energy-related CO_2 emissions embodied in international trade using a global input-output model”, in *Economic Systems Research*, Vol. 24, No. 2, pp. 113–139.

—; Yamano, N. 2016. *Estimating CO_2 emissions embodied in final demand and trade using the OECD ICIO 2015: Methodology and results,* OECD Science, Technology and Industry Working Papers 2016/05 (Paris, OECD).

Willer, H.; Lernoud, J. (eds). 2017. *The world of organic agriculture: Statistics and emerging trends 2017* (Frick, Bonn, Research Institute of Organic Agriculture (FiBL) and IFOAM – Organics International).

Wood, R.; Stadler, K.; Bulavskaya, T.; Lutter, S.; Giljum, S.; de Koning, A.; Kuenen, J.; et al. 2015. “Global sustainability accounting: Developing EXIOBASE for multi-regional footprint analysis”, in *Sustainability*, Vol. 7, No. 1, pp. 138–163.

World Bank. 2017. *World Development Indicators* (Washington, DC).