International Labour Organization

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

Global employment impact of COVID-19 crisis and recovery policies: methodology and sample results

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Global employment impact of COVID-19 crisis and recovery policies: Methodology and sample results
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Authors: Eva Alexandri, Francisco Arsenio, Bence Kiss-Dobronyi, Cornelia-Madalina Suta, Unnada Chewpreecha (Cambridge Econometrics)

Contributors: Marek Harsdorff (ILO)

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1. Introduction

Two years after the COVID-19 pandemic crisis began, the global economy has yet to fully recover. Pre-pandemic global GDP growth was relatively steady, averaging at around 3% p.a. for the last 9 years. The pandemic, however, brought the first global recession in a decade, plummeting global economic growth to -3.3% in 2020. Economic growth recovered in 2021, with GDP growth estimated at 5.7%. However, Russia's invasion of Ukraine in early 2022 has seriously threatened the continued recovery, leading to increased commodity and bottlenecks in global supply chains. GDP growth in 2022 is forecast at 2.9%[1], with 2023 and 2024 anticipated to grow at a similar pace, as fiscal and monetary policy stimuli implemented for the pandemic are expected to end.

Despite the COVID-19 crisis, emerging market and developing economies saw a 6.6% growth in 2021, however the World Bank forecast for 2022 shows a decrease of 3.4%. Advanced economies saw a 5.1 % growth in 2021, after the 4.6% contraction in 2020. However, growth in advanced economies is forecast to slow down to 2.6% in 2022, with a further slowdown projected for 2023-24 as fiscal and monetary policy support set up during the pandemic come to an end[2].

Global growth in 2021 has been supported by both fiscal and monetary policies, particularly in advanced economies (see Figure 1.1). In advanced economies, spending has begone to shift from the 2020 patterns, moving from direct policies to fight the pandemic restriction to supporting the economic recovery, and, in some cases looking further afield at transforming economies in line with sustainable goals. In emerging markets and low-income developing countries, on the other hand, limited scope for fiscal support has led to a reshuffling of funding towards pandemic-related issues[3].

However, the increased government support coupled with reduced revenue streams have led to increased debt, which makes future policy choices difficult particularly with the ongoing war in Ukraine.

The objective of this report is to illustrate the modelling of employment outcomes of country-based policies to stimulate the economy, notably a green and climate friendly economy (called policy archetypes). They are included in the Global Recovery Observatory (GRO) database.

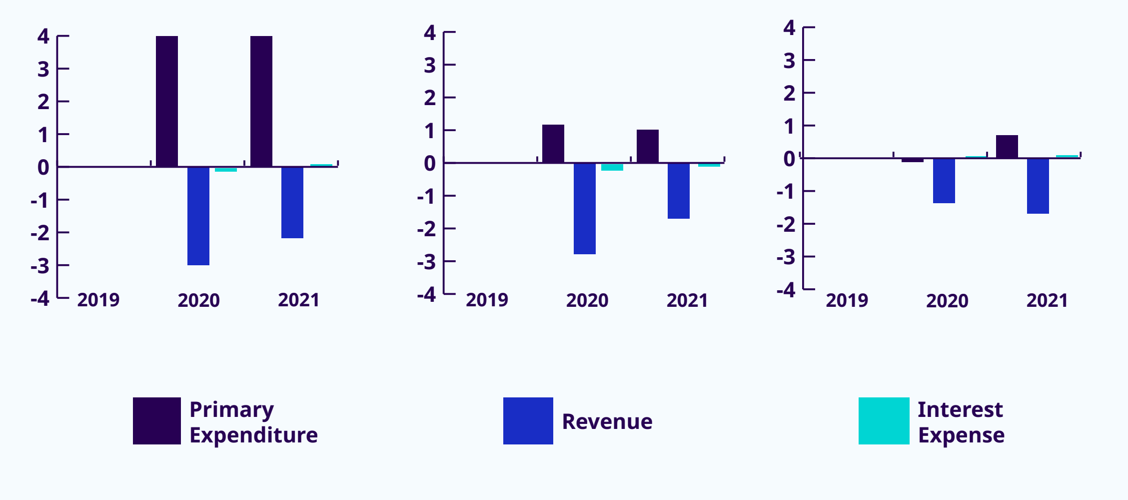
The report is structured as follows. Chapter 1 presents the methodology to model the real economy impacts of policies put in place to help the recovery from the COVID-19 pandemic. Chapter 2.3 briefly presents the global results.

1 World Bank (2022), See: Global Economic Prospects June 2022 (worldbank.org)

2 World Bank (2022).

3 IMF, (2021). See: Fiscal Monitor, October 2021 (imf.org)

Figure 1.1: The effect of the COVID-19 pandemic on the forecasts of fiscal aggregates (Real values, deviation from projection as a percentage of 2019 GDP, simple average)



Note(s): All quantities are converted into 2019 prices using the projected evolution of the GDP deflator
Source(s): IMF, (2021) , World Economic Outlook Database; and IMF staff estimates.

2. Modelling the real economy impacts

2.1 Introduction

This chapter illustrates how selected policy archetypes from the GRO 2022 February methodology can be grouped into general macroeconomic modelling approaches. The input diagrams in the following sections also demonstrate what kind of inputs and parameters are necessary for the modelling process.

All sub-archetype policies (160+), in some way or the other, impacts the economy mainly through four channels, with two additional channels for 'green' investments. The green measures, in addition to providing an economic stimulus have directly quantifiable positive environmental impacts:

1. Capital investment (e.g. Infrastructure, Buildings)
    a. Traditional
    b. Green
2. Spending on services (e.g skills training and healthcare)
3. Subsidies (e.g. feed-in-tariffs); and
4. Taxes (e.g. Energy-, Carbon-, Value Add Tax)
    a. General (e.g VAT and income)
    b. Energy / carbon taxes

Cambridge Econometrics' global E3ME model provides an economic framework with which to evaluate the employment effects of above archetype policies, among other. Behavioural relationships in the model are estimated using econometric time-series techniques applied to a database that covers the period from 1970 onwards, on an annual basis. A core feature of the model is its treatment of technology, which will be key to meeting many of the world's policy challenges. The Future Technology Transformation (FTT) models of technology diffusion in E3ME provide a representation of the adoption of new low-carbon technologies. E3ME extends its treatment of the economy to cover physical measures of energy, food, and material consumption, including carbon emissions. The main data sources for European countries are Eurostat and the International Energy Agency (IEA), supplemented by the OECD's STAN database and other sources where appropriate. For regions outside of Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using custom software algorithms.

2.2 Classification of GRO archetypes

The next section shows a potential classification of GRO archetypes to these channels.

Table 2.1: How (archetype) Policies impact the Real Economy

Selected archetypes GRO – 2022 February	1. Capital investment		2. Spending on services	3. Subsidies	4. Taxes	
	General capital investment	'Green' capital investment	Spending on services	Subsidies	General taxes	Energy/ carbon taxes
T: Electric vehicle incentives				X		
U: Electronic appliance and efficiency incentives				X		
V: Green market creation			X			
W: Other incentive measures				X		
X: Worker retraining and job creation			X			
Y: Education investment (non-infrastructure)			X			
Z: Healthcare investment (non-infrastructure)			X			
α: Social and cultural investment (non-infrastructure)			X			
β: Communications infrastructure investment	X					
γ: Traditional transport infrastructure investment	X					
δ: Clean transport infrastructure investment		X				
: Traditional energy infrastructure investment	X					
η: Clean energy infrastructure investment		X				
θ: Local (project-based) infrastructure investment	X	X				
γ: Building upgrades and energy efficiency infrastructure investment		X				
γ: Natural infrastructure and green spaces investment		X				
λ: Other large-scale infrastructure investments	X	X				
μ: Armed forces investment	X		X			
π: Disaster preparedness and capacity building investment	X		X			
σ: General research and development investment			X			
τ: Clean research and development investment			X			
L: Income tax cuts					X	
M: VAT and other goods and services tax cuts					X	
new A: Energy taxes						X
new B: Carbon tax						X
new C: Removal of fossil fuel subsidies						X

Source(s): Cambridge Econometrics.

2.3 General approach for each channel

In this section we present our approach in applying Cambridge Econometrics' E3ME model to assess the employment, environment and economic impacts of the above classified policy options.

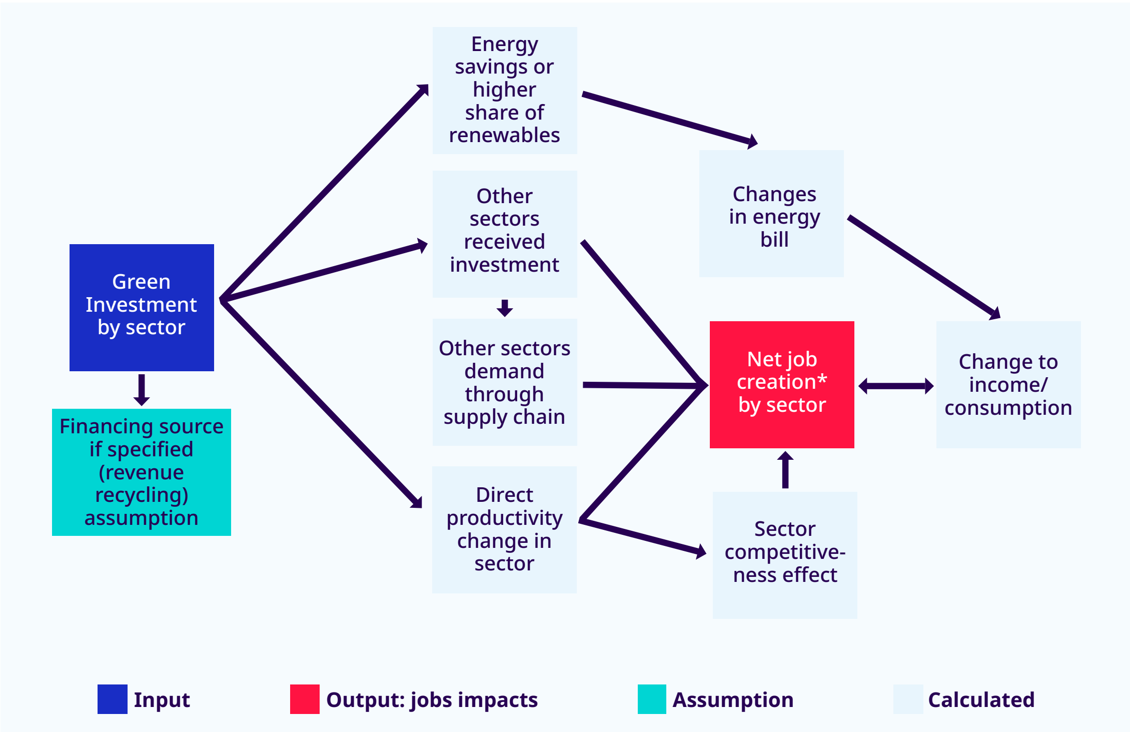
Figure 2.1 summarises how E3ME can capture the impact of green investment measures. The main input in the model (the blue box) is the green investment by sector. An assumption will have to be made as to how this investment is financed (e.g. carbon tax, borrowing, foreign aid etc.). This investment shock will lead to changes in the initial (direct) sector but also other sectors of the economy (and which are captured by the model). For example, by increasing investment in renewable energy, the share of renewables will increase. In countries that are more dependent on imported fossil fuels, this may lower such imports. Moreover, in a world of higher fossil fuel prices, a switch to renewables may help to shield consumers from higher energy prices, helping to maintain disposable incomes relative to the counterfactual case. This may in turn maintain demand and employment (the pink box) in the economy.

General capital investment is modelled in a similar way. Figure 2.2 the modelling exercise of public infrastructure investment will assume the increase in investment of the public infrastructure in a specific sector (e.g. transport infrastructure; communication infrastructure).

Figure 5 summarises the application of a subsidy on a product. The direct impact of a subsidy is that consumers face lower prices which in turn lead to higher demand. The net job creation arises through the direct effect of the subsidy in the sector, but also the indirect effect via supply chains (including through international trade).

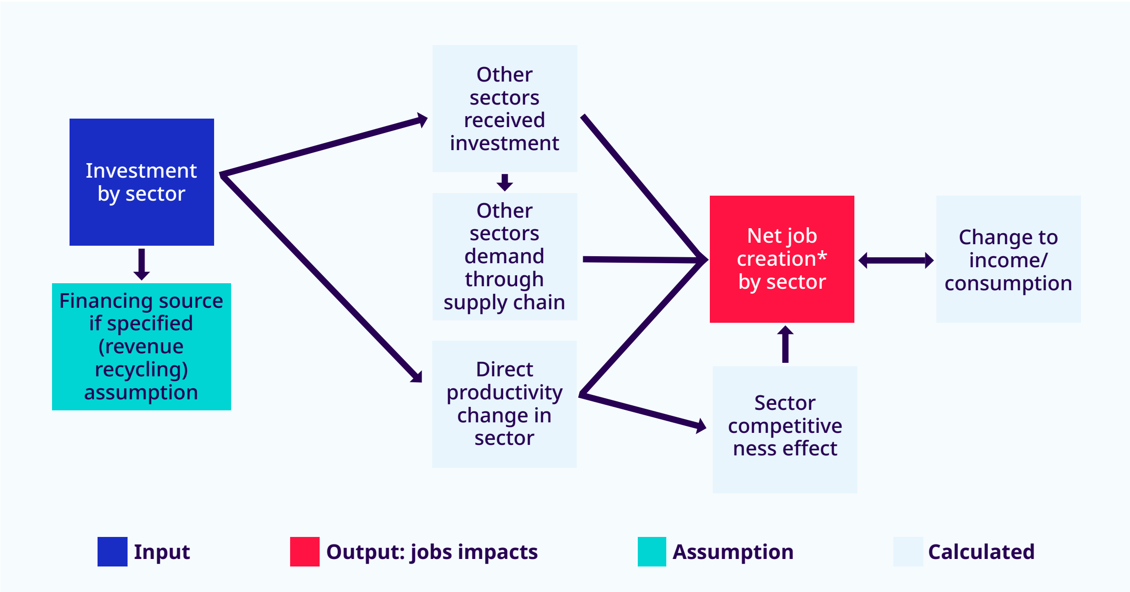
Figure 2.4, Figure 2.5 and Figure 2.6 present how the other types of interventions can be modelled.

Figure 2.1: How green investment can be modelled in E3ME



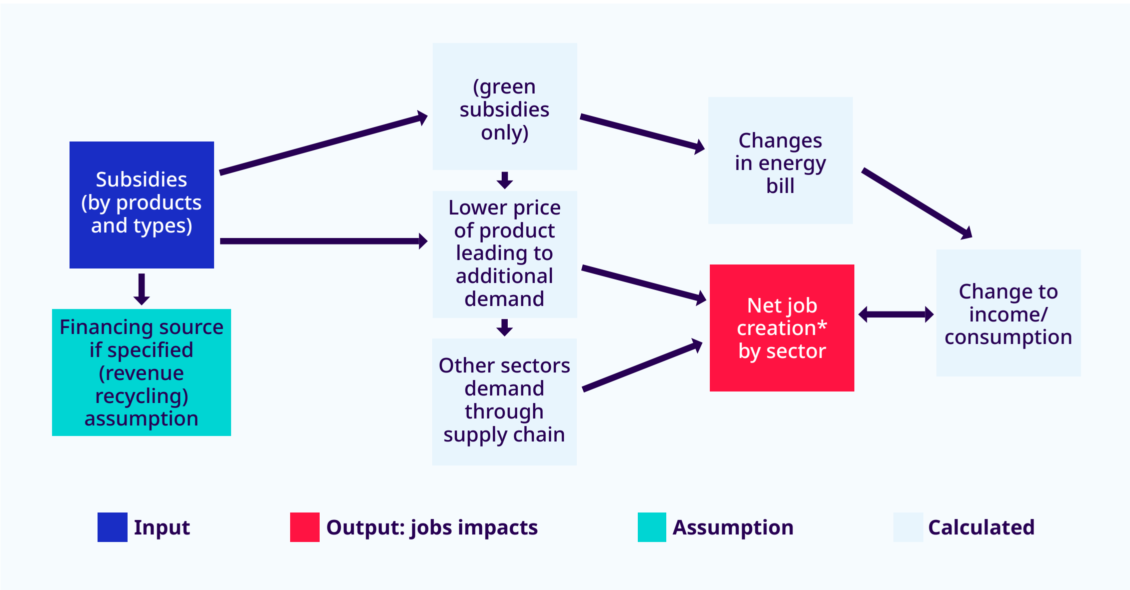
Note(s): *Net job creation includes direct, indirect and induced job creation.*
Source(s): *Cambridge Econometrics.*

Figure 2.2: General capital investment



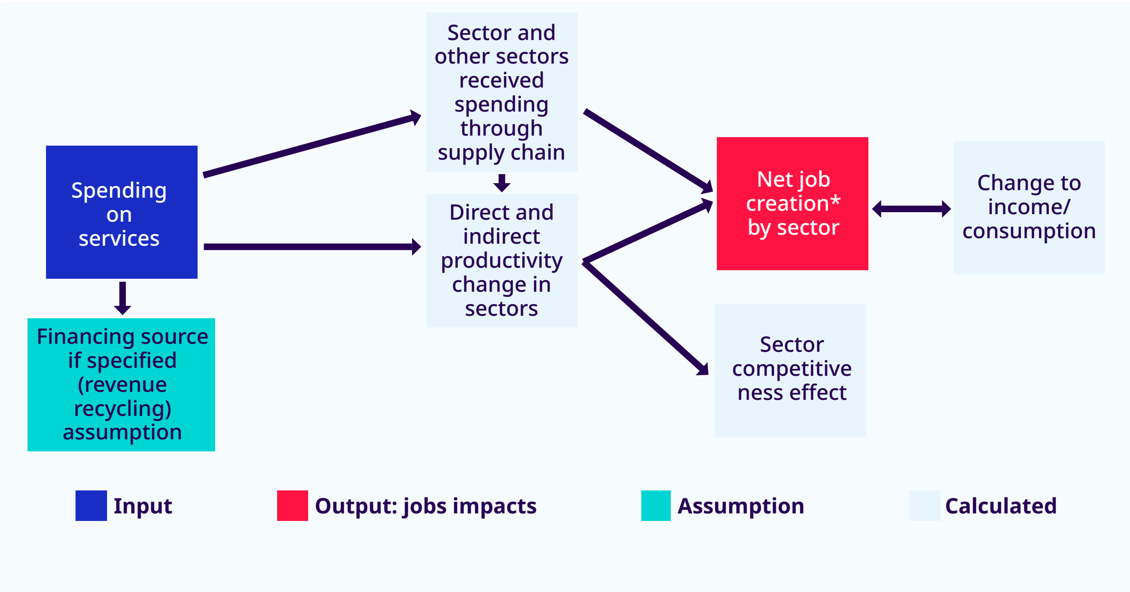
Note(s): Net job creation includes direct, indirect and induced job creation.
Source(s): Cambridge Econometrics.

Figure 2.3: How subsidies can be modelled in E3ME



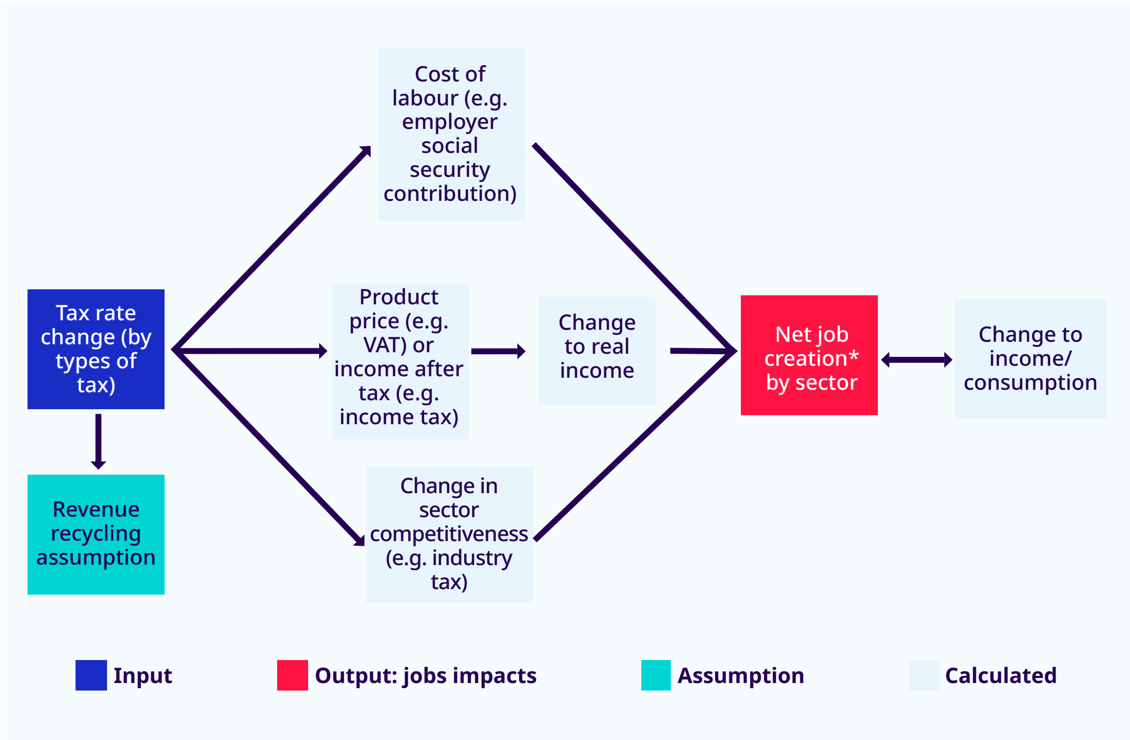
Note(s): Net job creation includes direct, indirect and induced job creation.
Source(s): Cambridge Econometrics.

Figure 2.4: How spending on services can be modelled in E3ME



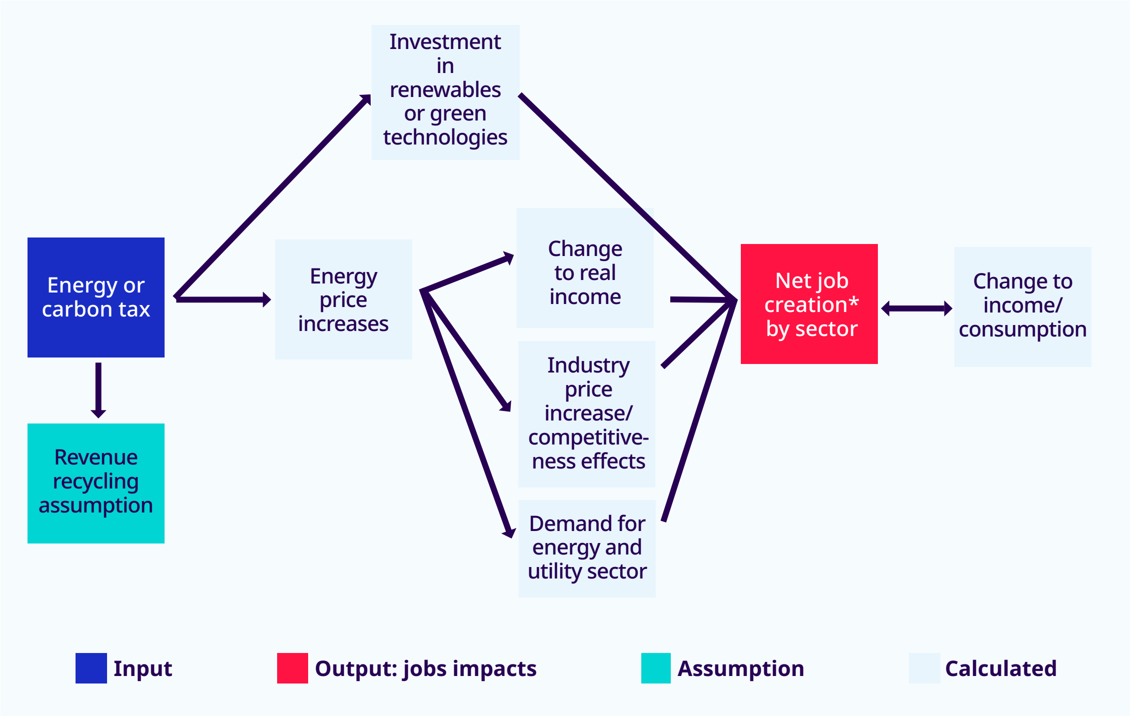
Note(s): Net job creation includes direct, indirect and induced job creation.
Source(s): Cambridge Econometrics.

Figure 2.5: How changes in general taxes can be modelled in E3ME



Note(s): Net job creation includes direct, indirect and induced job creation.
Source(s): Cambridge Econometrics.

▶ **Figure 2.6: How energy/carbon taxes can be modelled in E3ME**



Note(s): Net job creation includes direct, indirect and induced job creation.
Source(s): Cambridge Econometrics.

2.4 Financing and revenue recycling

Financing and revenue recycling is included in all input diagrams as an assumption need to be made about the sources of the investments and incentives.

In E3ME modelling, assumptions can be made on (1) budget balancing or (2) partial budget balancing, which means that we assume that policies have to be paid (at least partially) for from some new government revenue source. Tax / subsidy changes are the usual option for balancing, i.e. given a public investment policy (/program) we might introduce at the same time the removal of fossil fuel subsidies to finance the investment (revenue recycling).

In addition, policies that are financed from external sources (e.g. FDI or aid) can also be modelled. In this case we either do not need budget balancing or only need partial budget balancing.

An important consideration in this exercise is the regressive nature of energy or carbon taxes. It is the poor households, who spend a larger share of their income on energy, housing and food, which increase in price with a carbon tax. So the poor households are most impacted by strong carbon taxation. So in order to shield the poor households, carbon taxes need to be recycled and redistributed to compensate the poor households for their higher expenditures on basic need. The reduction of the value added tax (VAT) rate is a simplified way to address the regressive nature of carbon taxes. This is because a VAT is also a regressive tax, which impacts the poor households most as they spend a larger share of their income on basic goods.

Table 2.2: Examples of possible financing sources in the model

Income tax change
VAT and other goods and services tax change
Energy taxes (on fuels)
Carbon tax (based on carbon content)
Removal of fossil fuel subsidies
External sources (i.e. aid or expected FDI)

Source(s): Cambridge Econometrics.

3. Employment impacts

3.1 Introduction

The purpose of the modelling exercise in the report is to estimate the net employment outcomes resulting from some of the above archetype policies that have been implemented at global level during 2022-24.

The E3ME model takes into consideration the different economic realities and aspects of various world countries, as well as the recovery policies by them implemented; thus, becoming an adequate tool to estimate the impact of these policies on employment. Specifically, the exercise in question utilised the fiscal archetype policies present at the Global Recovery Observatory (GRO) database.

3.2 Modelling assumptions

This section presents the actual assumptions used in the modelling exercise in line with the methodology presented in Chapter 2.

The modelling results present the effect of the combined green and non-green recovery policies compared to a business-as-usual (BAU) case, which considers already adapted rescue measures and effects observed in 2020. Modelled policies include green as well as other fiscal policies: increased spending on healthcare, communication investment, etc.

Investment assumptions

The source of policies for the global scenario is Global Recovery Observatory (GRO) database[4]. The policies were aggregated across the following ten selected policy archetypes; each with a specific channel through which the employment is affected:

- **T - Electric vehicle incentives**. Investments under archetype T are treated in the model as subsidies to electric vehicle. The investment is assumed to be split in equal manner between economy, mid-range, and luxury electric vehicles and the cost of each of these vehicle types is assumed to be 30, 40, and 80 thousand Euros, respectively.
- **V - Green market creation**. Investments in green market creation are modelled as exogenous investments in public administration. Moreover, this type of investment also reverberates in terms of increased energy efficiency across the economy's industries. The model assumes that for every 1.3 million euros invested in an archetype lambda policy 1 ktoe of energy demand is avoided. This decrease in demand impacts the use of heavy oil, gas, and coal across all industrial sectors, proportionally with these fuels' global demand, in favour to the use of electricity.
- **Z - Healthcare investment (non-infrastructure)**. This type of investment corresponds to an increase in government current expenditure in healthcare.
- **β (beta) - Communications infrastructure investment**. This archetype's investments are modelled as exogenous increases in investment on the communications and computer services sectors. The increase in each sector is proportional to the yearly endogenous investment on each sector.

4 Concerning the archetypes used in this modelling exercise, the policies in the GRO database have been categorised according to a framework of 24 distinct archetypes. These archetypes consider the interventions in different sectors of the economy and are classified according to the degree of being considered "green policies". This classification varies between green, partially green, and non-green, or adaption.

- γ (gamma) - **Traditional transport infrastructure investment**. Investments categorised with this archetype are integrated in the model as an exogenous increase on land transport investment.
- η (eta) - **Clean energy infrastructure investment**. The model takes archetype eta's investments as subsidies to onshore and offshore wind-based power generation.
- λ (lambda) - **Buildings upgrades and energy efficiency infrastructure investment**. Investments in this archetype are modelled as an exogenous investment in public administration. This type of investment also creates an increase of energy efficiency in the economy equivalent to a decrease of 1 ktoe of energy demand for every 1.3 million euros invested. This decrease in demand impacts the use of heavy oil, gas, and coal across all industrial sectors, proportionally with these fuels' global demand.
- π (pi) - **Other large-scale infrastructure investments**. This type of investments is assumed to be an exogenous increase on public administration within the model.
- σ (sigma) - **Armed forces investment**. This type of investment corresponds to an increase in government current expenditure in defence.
- φ (phi) - **General research and development investment**. Investments classified under this archetype are assigned to research and development in pharmaceuticals (45%), electronics (45%), and computing (10%) as an approximation of current global R&D structure.

It is assumed that these policies are implemented globally starting from 2022 and ending in 2024. The scale of the investment is indicated in Table 3.1. The total investment EUR 3,671 billion, evenly split across all years.

Table 3.1: Additional recovery spending ($bn) by archetype and year

Architype	Total investment	2022
T	31	8
V	206	52
Z	51	13
β (beta)	544	138
γ (gamma)	573	145
η (eta)	141	36
λ (lambda)	45	11
π (Pi)	432	109
σ (sigma)	17	4
φ (phi)	338	86
Other	1,293	327
Grand Total	**3,671**	**929**

Source(s): Global Recovery Observatory (GRO) database.

Financing assumptions

The following assumptions have been made regarding the financing of the investment:

1. In 2022, 30% of the investment is a result of reshuffling of other government expenditure, with the rest financed by issuing debt.
2. From 2023 onwards, a global carbon price has been introduced to power generation and industry; revenues from the carbon pricing mechanism are used to finance the investment and where enough is left over to reduce standard VAT rates.
3. The carbon pricing continues to 2030, with revenues used to reduce standard VAT rates.

Table 3.2 summarises the carbon pricing assumptions used in the modelling. The baseline prices apply for EU-27, with only power generation resulting in revenues (auctioned under the EU-ETS). In the scenario the price is applied to both power generation and industry and generates revenues from all sectors.

Caveats

The modelling assumes not crowding out effect caused by these investments due to the assumption of non-limited money supply. While these policies are long-term in nature, the results in this report are presented up to 2030 only.

An important caveat is the fact that the model does not take into consideration the efficiency and productivity gains resulting from the construction and enhancing of infrastructure that came to be from the execution of the recovery policies. As such, one should consider that the efficiency and productivity gains in the modelled economy are underestimated.

3.3 Employment outlook

Economy-wide outcomes

Figure 3.1 summarises the impacts at global level on employment and GDP from considered policies (green and other fiscal policies) as compared to the baseline (which considers COVID-19 impacts and rescue policies implemented in 2020 and 2021). Over 2022-24 the GDP impacts are mainly driven by the investment stimulus package. Impacts from 2025 onwards are a response to the carbon price and VAT changes. Employment follows a similar trend to GDP, albeit on smaller scale and with a bit of lag in response.

Initially, policies boosting investment lead to higher economic activity and hence employment. These policies include large-scale infrastructure projects as well as other measures with instant effects on investment activity. This is later followed by job gains from higher consumption levels and economic activity related to climate transition – incentivized by carbon pricing.

The energy efficiency savings supported by the stimulus package are expected to lead to a decrease in final energy consumption (Figure 3.2). The savings coupled with the global carbon price for power generation and industry are expected to lead to significant decrease in CO2 emissions by 2030.

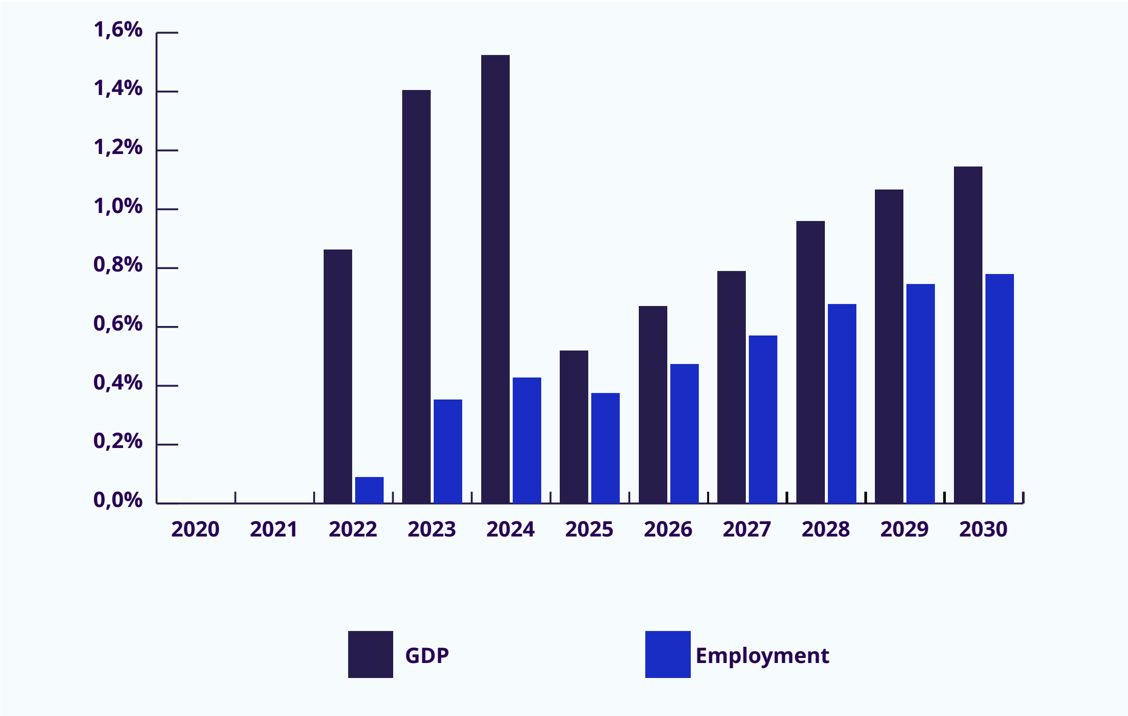
As mentioned above the global impact on GDP over 2022-24 is mainly driven by the investment stimulus package (Figure 3.3). In 2022, a slight

Table 3.2 Carbon price assumptions, EUR/tCO_2

	2023	2025	2030
Baseline (EU-27 only)	22.8	25.6	34.3
Scenario (Global)	58.4	66.8	90.5

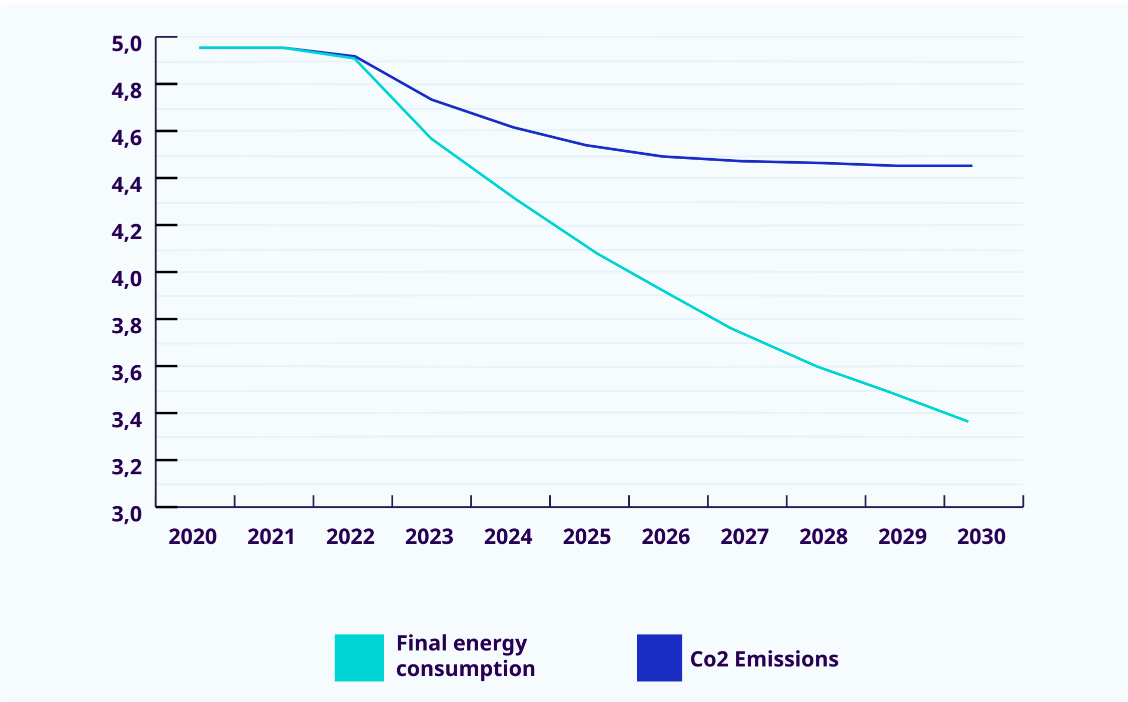
Source(s): Global Recovery Observatory (GRO) database.

▶ **Figure 3.1: Global macroeconomic impacts, % difference from baseline**



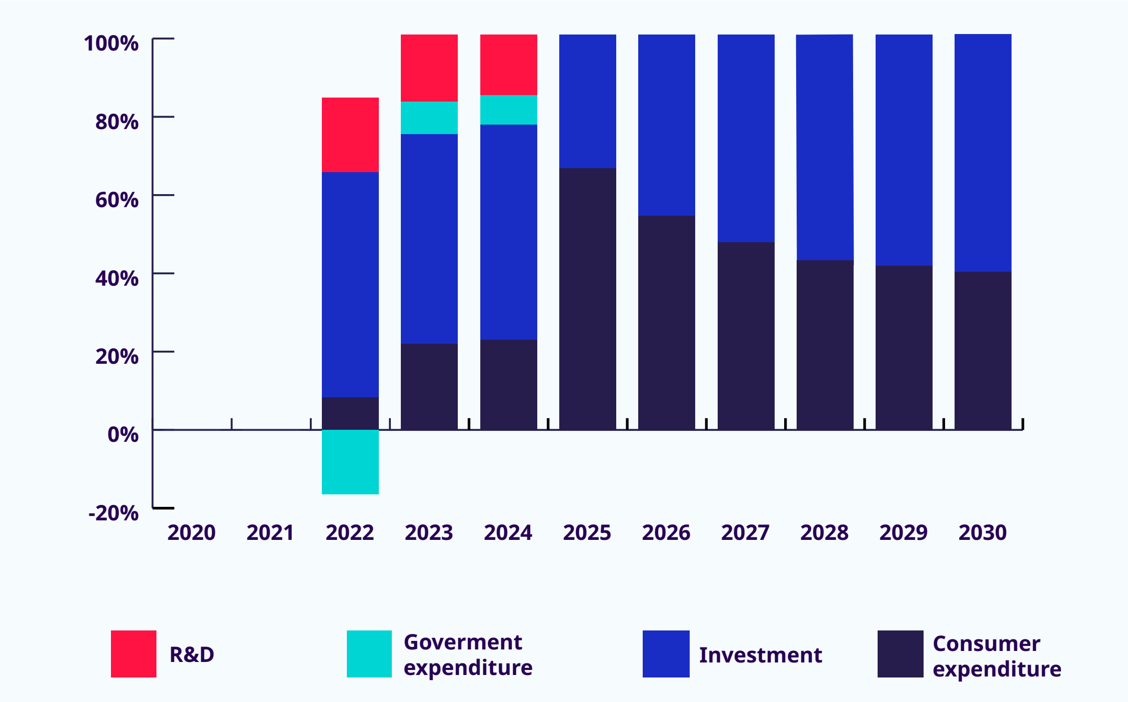
Source(s): Cambridge Econometrics' E3ME

▶ **Figure 3.2: Global energy and CO_2 emissions, % difference from baseline**



Source(s): Cambridge Econometrics' E3ME

Figure 3.3: Contributions to Global change in GDP, share of absolute change from baseline



Source(s): Cambridge Econometrics' E3ME

decrease in government expenditure can be observed, as the government shuffles part of its expenditure towards the investment stimulus. The increase in economic activity in the first three years is mainly driven by investment and R&D. With the introduction of the carbon price and the recycling of some of the revenues resulting from it towards VAT reduction, consumer expenditure picks up and becomes a major contributor to GDP growth by 2030. The carbon price also leads to an increase in investment activity by the electricity supply sector, as it tries to find cheaper generating technologies now that the carbon pricing has made coal more expensive. Towards 2030, the main contributors to the positive change in GDP are consumer expenditure and investment, particularly by the electricity supply sector.

Most sectors are expected to see an increase in employment (Table 3.3), with the exception of extractive industries. The increased investment activity is expected to lead to increased activity in manufacturing and sectors in it supply chain. The reduced VAT rates are expected to lead to higher disposable incomes and thus expenditure, benefiting sectors producing consumer goods and services. On the other hand, higher energy efficiency and the carbon prices are expected to lead to a reduced demand in coal and oil & gas extraction, leading to a decrease in employment in these sectors. The energy efficiency savings and carbon pricing are also expected to lead to a decrease in economic activity and employment in the gas supply sectors, however this impact is mitigated by higher activity and employment in the electricity supply sector.

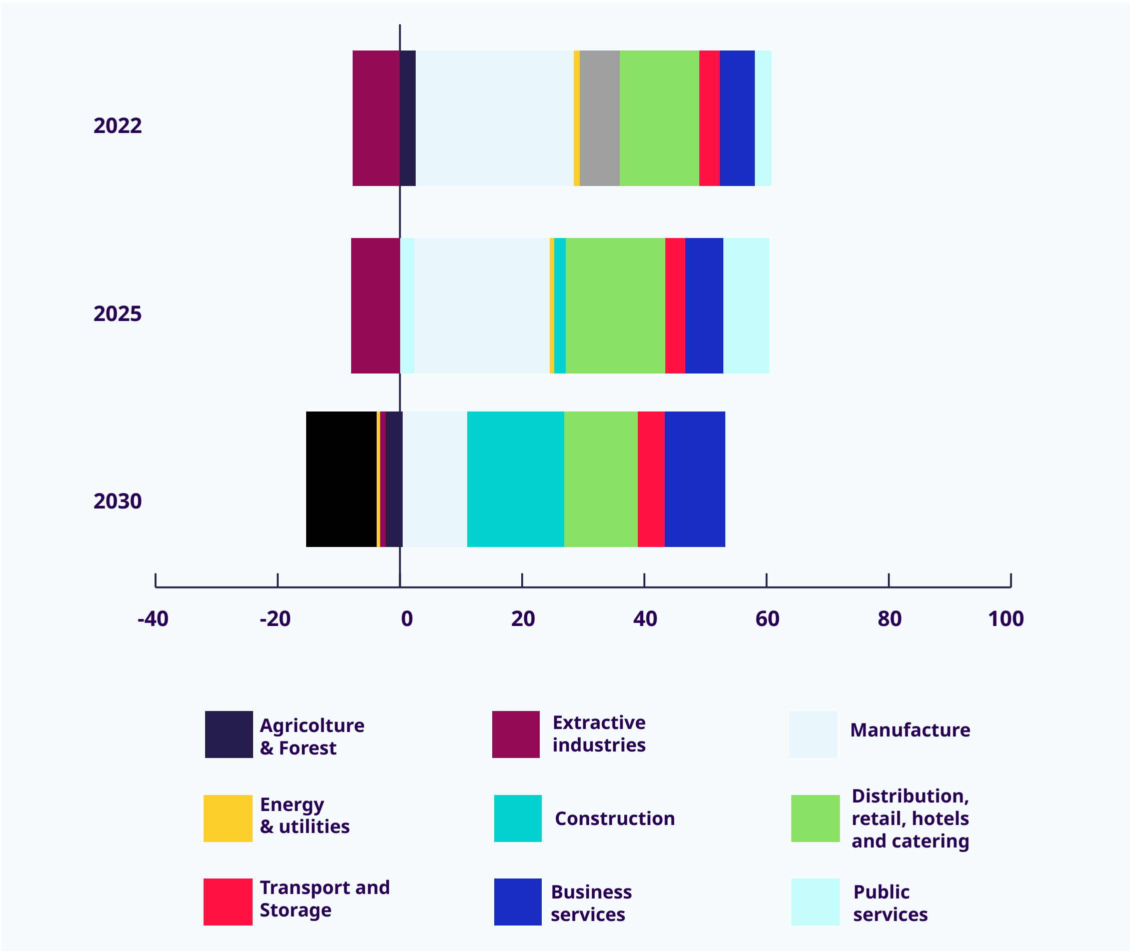
Manufacture, and Distribution, retail, hotels and catering are the sectors with the largest contribution to overall employment increase compared to baseline (Figure 3.4). Manufacture employment benefits from the increased investment activity, while increased consumer activity leads to higher employment growth in distribution and retail-related services. In 2022, the increase in employment is mitigated by the reduction in government expenditure as governments redirect some of their expenses towards investment stimulus packages. From 2025 onwards, extractive industries have the largest negative impact on employment change, as economic activity in coal and, oil and gas extraction is expected to decrease.

Table 3.3 Global employment change by sector, % difference from baseline

	2022	2025	2030
Agriculture & forestry	0.0	0.1	0.2
Extractive industries	-0.2	-4.5	-8.0
Manufacture	0.2	1.0	2.2
Energy & utilities	-0.1	0.2	0.7
Construction	0.6	0.2	1.4
Distribution, retail, hotels and catering	0.2	0.7	1.1
Transport and Storage	0.3	0.5	1.0
Business services	0.2	0.3	0.5
Public services	-0.2	0.4	0.3

Source(s): Cambridge Econometrics' E3ME

Figure 3.4: Sectoral contribution to change in employment, share of absolute difference from baseline



Source(s): Cambridge Econometrics' E3ME

Appendix A Annex

A.1 Overview

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes. The global version of E3ME provides:

- better geographical coverage
- better feedbacks between individual European countries and other world economies
- better treatment of international trade with bilateral trade between regions
- new technology diffusion sub-modules

This model description provides a short summary of the E3ME model. For further details, please read the full model manual available online from www.e3me.com

A.2 E3ME basic structure and data

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2020 and the model projects forward annually to 2100. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

A.3 The main dimensions of the model

The main dimensions of E3ME[5] are:

- 70 global regions, including all G20 and EU Member States explicitly, plus a set of regions to meet global totals
- 43 economic sectors in each region, with additional detail in Europe
- a timeframe covering 1970-2050 on an annual basis
- 43 categories of household expenditure
- 22 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the 6 GHG's monitored under the Kyoto Protocol

A.4 Standard outputs from the model

As a general model of the economy, based on the full structure of the national accounts, E3ME is

5 Dimensions | Features | E3ME | Cambridge Econometrics

capable of producing a broad range of economic indicators. In addition, there is range of energy and environment indicators. The following list provides a summary of the most common model outputs:

- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade)
- sectoral output and GVA, prices, trade and competitiveness effects
- international trade by sector, origin and destination
- consumer prices and expenditures
- sectoral employment, unemployment, sectoral wage rates and labour supply
- energy demand, by sector and by fuel, energy prices
- CO2 emissions by sector and by fuel
- other air-borne emissions
- material demands

This list is by no means exhaustive and the delivered outputs often depend on the requirements of the specific application. In addition to the sectoral dimension mentioned in the list, all indicators are produced at the national and regional level and annually over the period up to 2100.

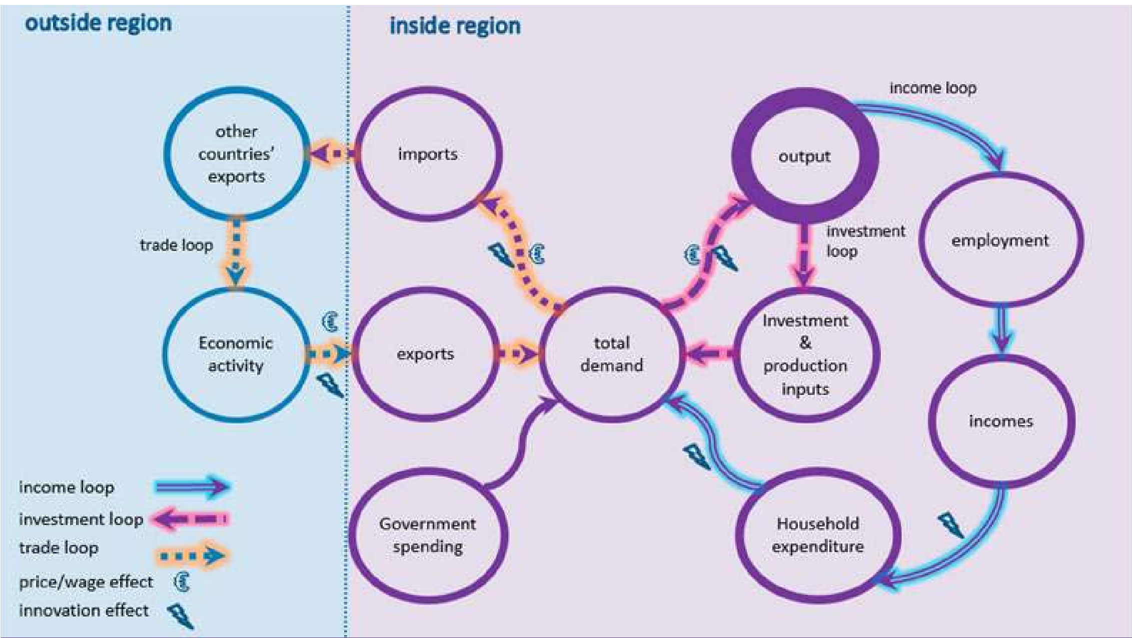
A.5 E3ME's economic module

Figure A.1 shows how E3ME's economic module is solved for each region. Most of the economic variables shown in the chart are solved at the sectoral level. The whole system is solved simultaneously for all industries and all regions, although single-country solutions are also possible.

The loops of interdependency

As the figure suggests, output and employment are determined by levels of demand, unless there are constraints on available supply. The figure shows three loops or circuits of economic interdependence, which are described below. In addition, there is an interdependency between the sectors that is not shown in the figure. The full set of loops comprises:

Figure A.1.0.1: E3ME's basic economic structure



- Interdependency between sectors: If one sector increases output it will buy more inputs from its suppliers who will in turn purchase from their own suppliers. This is similar to a Type I multiplier.
- The income loop: If a sector increases output it may also increase employment, leading to higher incomes and additional consumer spending. This in turn feeds back into the economy, as given by a Type II multiplier.
- The investment loop: When firms increase output (and expect higher levels of future output) they must also increase production capacity by investing. This creates demand for the production of the sectors that produce investment goods (e.g. construction, engineering) and their supply chains.
- The trade loop: Some of the increase in demand described above will be met by imported goods and services. This leads to higher demand and production levels in other countries. Hence there is also a loop between countries.

A detailed description on how each component of demand is calculated can be found in the model manual[6]. Below is a short summary of the recently updated treatments.

Treatment of international trade

An important part of the modelling concerns international trade. E3ME solves for detailed bilateral trade between regions (similar to a two-tier Armington model). Trade is modelled in three stages:

- econometric estimation of regions' sectoral import demand
- econometric estimation of regions' bilateral imports from each partner
- forming exports from other regions' import demands

Trade volumes are determined by a combination of economic activity indicators, relative prices and technology.

The labour market

Treatment of the labour market is an area that distinguishes E3ME from other macroeconomic models. E3ME includes econometric equation sets for employment, average working hours, wage rates and participation rates. The first three of these are disaggregated by economic sector while participation rates are disaggregated by gender and five-year age band.

The labour force is determined by multiplying labour market participation rates by population. Unemployment (including both voluntary and involuntary unemployment) is determined by taking the difference between the labour force and employment. This is typically a key variable of interest for policy makers.

There are important interactions between the labour market equations. They are summarised below:

Employment = F (Economic output, Wage rates, Working hours, ...)

Wage rages = F (Labour productivity, Unemployment, ...)

Working hours = F (Economic output in relation to capacity, ...)

Participation rates = F (Economic output, Wage rates, Working hours, ...)

Labour supply = Participation rate * Population

Unemployment = Labour supply – Employment

6 https://www.e3me.com/wp-content/uploads/2019/09/E3ME-Technical-Manual-v6.1-onlineSML.pdf

The full specification for the econometric equations can be found in the detailed technical manual[7].

The role of technology

Technological progress plays an important role in the E3ME model, affecting all three E's: economy, energy and environment. The model's endogenous technical progress indicators (TPIs), a function of R&D and gross investment, appear in nine of E3ME's econometric equation sets including trade, the labour market and prices. Investment and R&D in new technologies also appears in the E3ME's energy and material demand equations to capture energy/resource savings technologies as well as pollution abatement equipment. In addition, E3ME also captures low carbon technologies in the power sector through the FTT power sector model.[8]

A.6 Comparison with CGE models and econometric specification

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches.

In a typical CGE framework, optimal behaviour is assumed, output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. In E3ME the determination of output comes from a post-Keynesian framework and it is possible to have spare capacity. The model is more demand-driven and it is not assumed that prices always adjust to market clearing levels.

The differences have important practical implications, as they mean that in E3ME regulation and other policy may lead to increases in output if they are able to draw upon spare economic capacity. This is described in more detail in the model manual.

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects[9], which are included as standard in the model's results.

A.7 Key strengths of E3ME

In summary the key strengths of E3ME are:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios
- its global coverage, while still allowing for analysis at the national level for large economies
- the econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to CGE models
- the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends.

7 https://www.e3me.com/wp-content/uploads/2019/09/E3ME-Technical-Manual-v6.1-onlineSML.pdf

8 See Mercure (2012).

9 Where an initial increase in efficiency reduces demand, but this is negated in the long run as greater efficiency lowers the relative cost and increases consumption. See Barker et al (2009).

A.8 Limitations of the approach

As with all modelling approaches, E3ME is a simplification of reality and is based on a series of assumptions. Compared to other macroeconomic modelling approaches, the assumptions are relatively non-restrictive as most relationships are determined by the historical data in the model database. This does, however, present its own limitations, for which the model user must be aware:

- The quality of the data used in the modelling is very important. Substantial resources are put into maintaining the E3ME database and filling out gaps in the data. However, particularly in developing countries, there is some uncertainty in results due to the data used.
- Econometric approaches are also sometimes criticised for using the past to explain future trends. In cases where there is large-scale policy change, the 'Lucas Critique' that suggests behaviour might change is also applicable. There is no solution to this argument using any modelling approach (as no one can predict the future) but we must always be aware of the uncertainty in the model results.

The other main limitation to the E3ME approach relates to the dimensions of the model. In general, it is very difficult to go into a level of detail beyond that offered by the model classifications. This means that sub-national analysis is difficult[10] and sub-sectoral analysis is also difficult. Similarly, although usually less relevant, attempting to assess impacts on a monthly or quarterly basis would not be possible.

10 If relevant, it may be possible to apply our E3-India or E3-US (currently under development) models to give state-level analysis.

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International Labour Organization
4 route des Morillons
CH-1211 Genève 22
Switzerland

9 789220 385562