Module 3 – Overview of modeling approaches and models

Course: Inclusive Green Economy (IGE) modelling

Date / Place / Name

OVERVIEW

1 Overview of methods

2 Overview of models

3 Interpretation of results

4 In depth review: Integrated Green Economy Modelling (IGEM) framework

1 Overview of Methods

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UNDERSTANDING SIMULATION MODELS

A model is a simplification of reality.

It includes variables and equations and uses data.

There are three main methods for solving equations:

optimization **econometrics** **simulation**

The method used influences the type of data inputs required and the approach to policy analysis.

REFLECTION POINT

Have you used models before?

What type of model, and for what type of analysis?

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METHODOLOGIES: OPTIMIZATION

Solves model equations by finding an optimal solution based on an “objective function”.

One or more “constraints” can be considered in the formulation of the objective function.

Optimization can lead to a snapshot (next optimal level), or a sequence of stages, with explicit time and a semi-continuous approach.

POLL

What stage of the policymaking process can profit the most from the use of **optimization models**?

A. Issue identification

B. Policy formulation

C. Policy assessment

METHODOLOGIES: ECONOMETRICS

Estimates the correlation between one or more variables in the system.

Uses historical trends to forecast possible future changes.

Assumes that the drivers of change of the past remain relevant (but not the only ones) for the future.

Allows the analysis to be extended to capture more indicators, if data is available.

POLL

What stage of the policymaking process can profit the most from the use of **econometric models**?

A. Issue identification

B. Policy formulation

C. Policy assessment

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METHODOLOGIES: SIMULATION

Focuses on “causal-descriptive” relations.

Represents drivers of change of the past, as well as possible emerging ones for the future.

Can be top-down, such as System Dynamics, or bottom-up, such as Agent-Based Modelling.

Emphasizes how structure drives behavior (feedback loops) and shifts dominance of drivers of change.

POLL

What stage of the policymaking process can profit the most from the use of **simulation models**?

A. Issue identification

B. Policy formulation

C. Policy assessment

SUMMARY OF METHODOLOGIES

METHODOLOGY	MODEL FORMULATIONS	TIME HORIZON	ANALYSIS APPROACH	TYPE OF SIMULATION
Optimization	Constraints, objective function	Snapshot, short term	Bottom up (sectoral), Top-down (macro)	Target based, backward looking
Econometrics	Correlations, causal	Short and medium term	Top-down	Forward looking
Simulation	Causal, descriptive	Short, medium and long-term	Top-down, Bottom-up	Forward looking

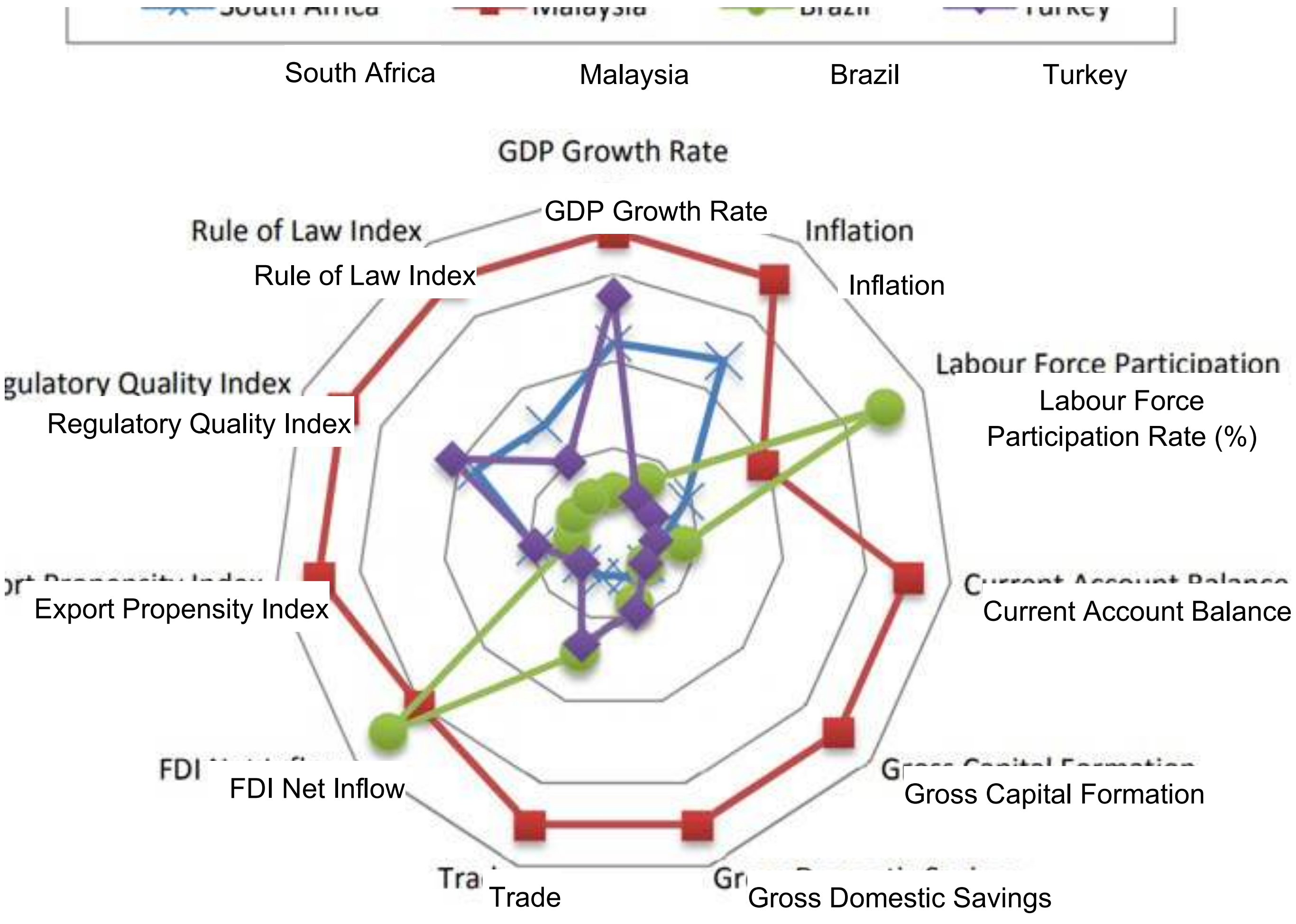
TYPES OF ASSESSMENT

ECONOMIC ASSESSMENT

Designed to support the analysis of policies, projects and investments with respect to their expected economic outcome.

An example of this type of framework is the methodology for conducting feasibility studies.

Macroeconomic Indicators

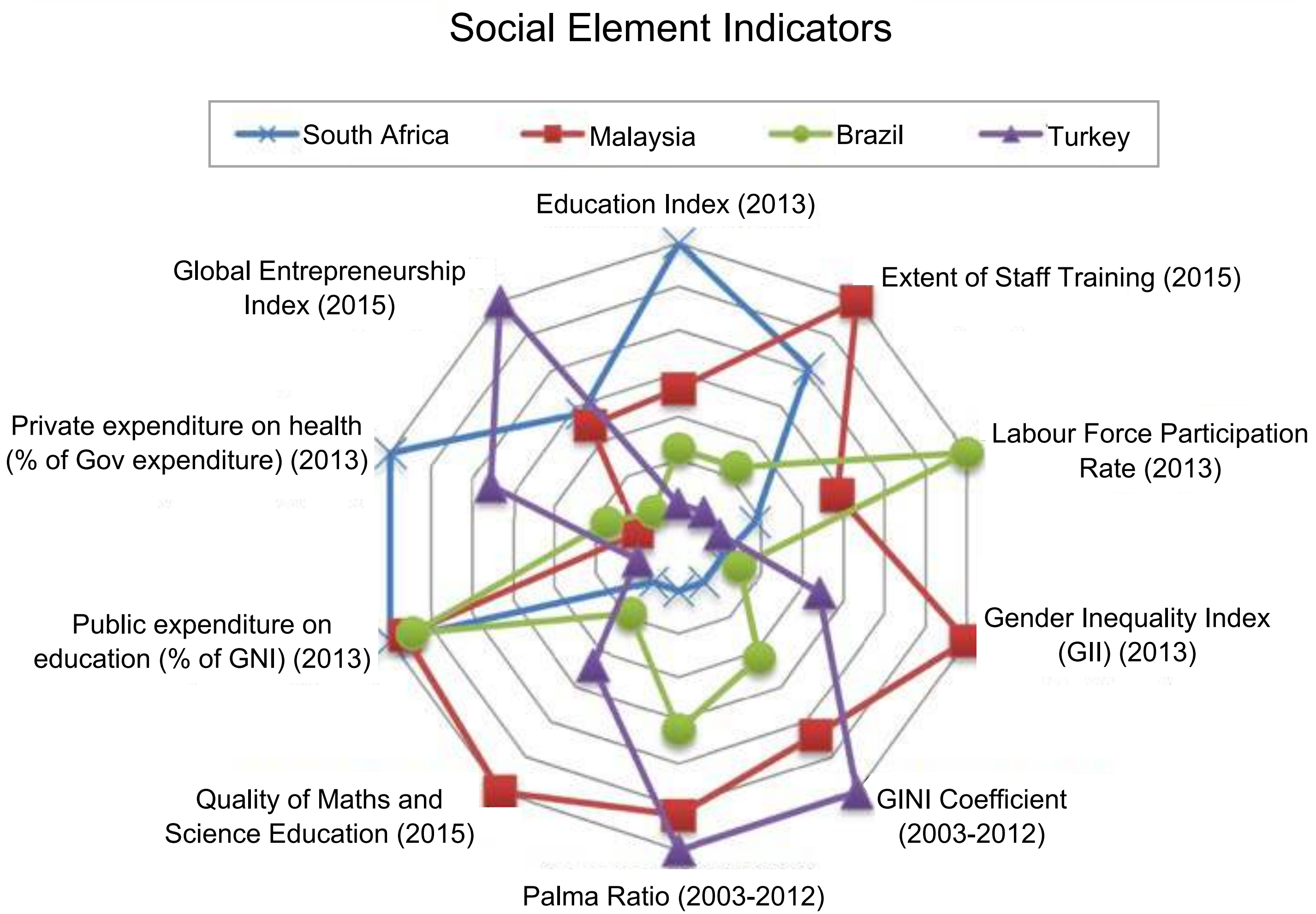


Source: ILO, 2016

SOCIAL ASSESSMENT

Provides guidance on how to evaluate policy impacts on different social groups, and review and monitor key governance indicators.

An example is Poverty and Social Impact Analysis (PSIA), which facilitates the assessment of policy inclusiveness and pro-poor orientation.

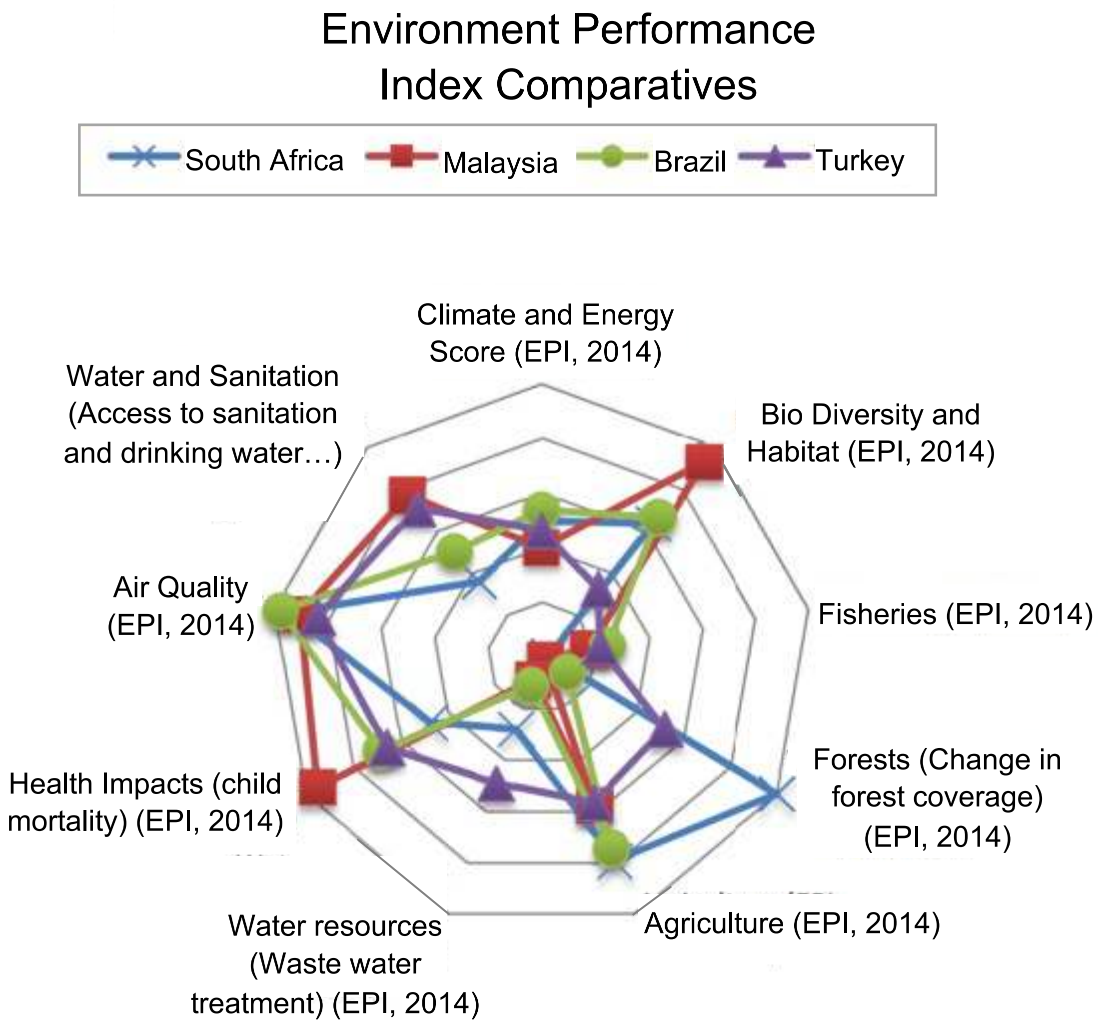


Source: ILO, 2016

ENVIRONMENTAL ASSESSMENT

Includes frameworks that combine tools for the evaluation of the environmental impacts of development strategies, policies, projects and investments.

Examples include:
(1) Strategic Environmental Assessment (SEA)
(2) Environmental Impact Assessments (EIA)



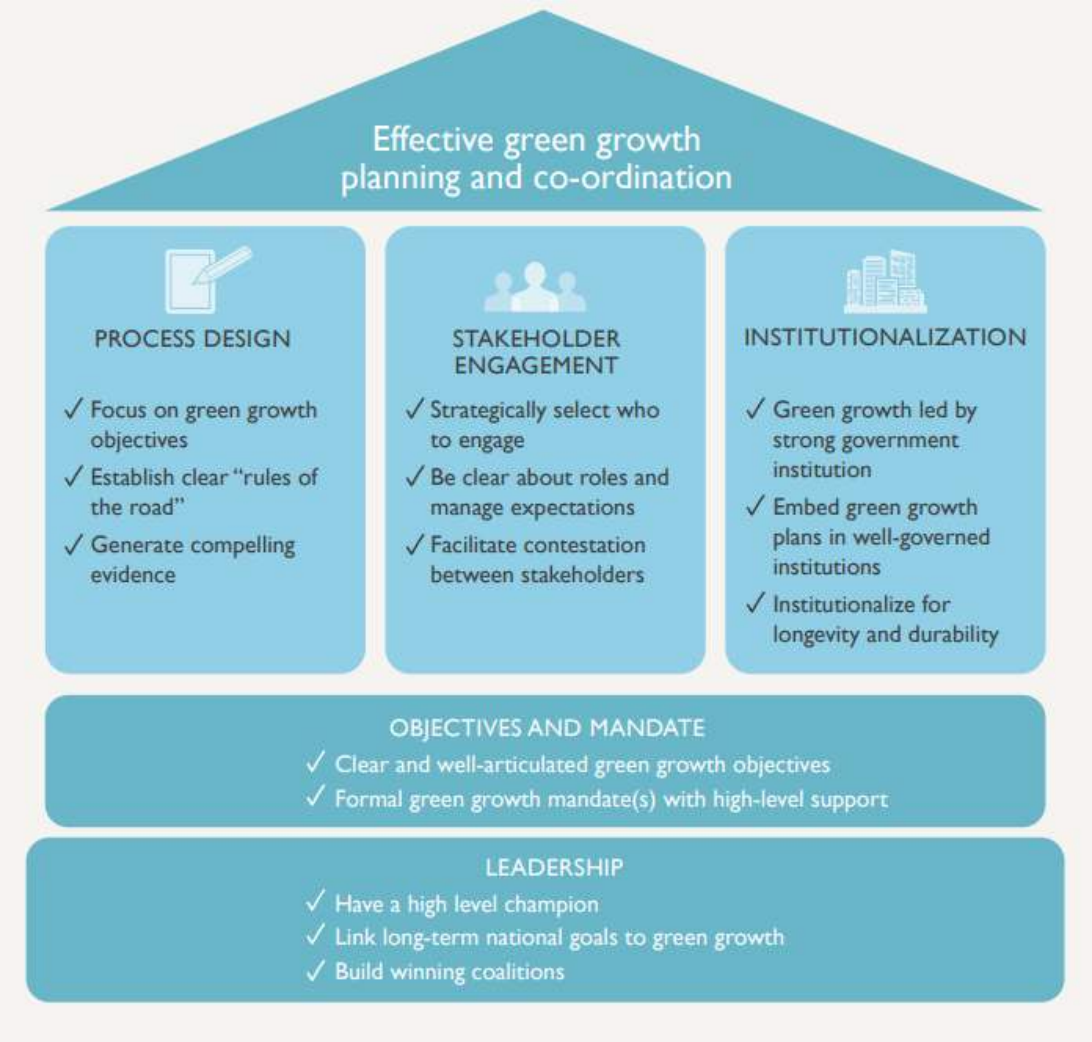
Source: ILO, 2016

GOVERNANCE ASSESSMENT

IGE policies require efficient and transparent institutional frameworks and processes at both the national and local levels.

There are six key principles: participation, fairness, decency, accountability, transparency and efficiency.

Foundations for green growth planning and co-ordination



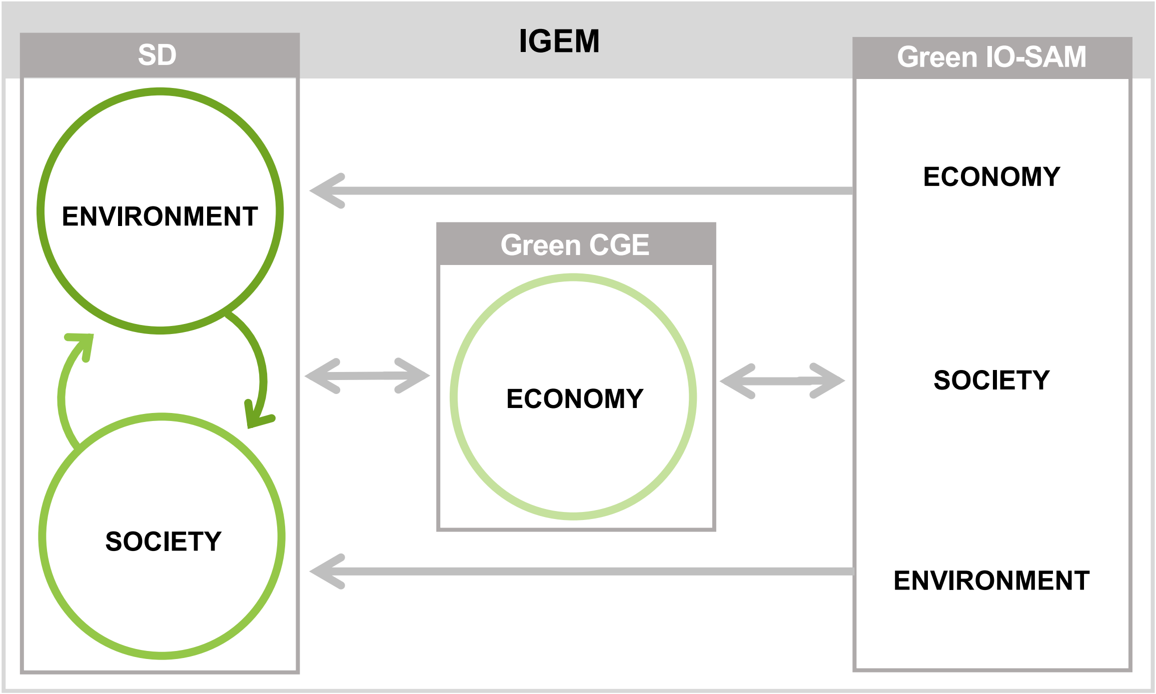
Source: GGBP, 2014

INTEGRATED ASSESSMENT

An assessment that estimates policy outcomes for various sectors, economic actors and dimensions of development, as well as over time.

As an example, Decision Support Systems (DSS) provide valuable guidance to decision makers for the integrated evaluation of IGE policies.

The structure of the integrated green economy modelling framework



Source: UNEP, 2017

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2 Overview of Models

OVERVIEW OF MODELS

Many models are available to support the assessment of the outcomes of IGE investments.

Some capture few, some many of the characteristics of the IGE.

Both qualitative and quantitative models can be used for IGE assessments.

OVERVIEW OF MODELLING APPROACHES

Refer to the underlying mathematical theories and frameworks that can be used to create and simulate (or solve) quantitative simulation models.

Usefulness of models depends on their match to the definition of a green economy, which depends on the local context, the quantitative outputs they generate to effectively inform decision-making, and how easy they are to customise and use.

MODELLING USEFULNESS DEPENDS ON THEIR SUPPORT OF THE POLICYMAKING PROCESS

Ex-ante modelling can generate “what if” projections on scenarios with no action, as well as the potential impact of proposed policies.

Ex-post modelling can support impact evaluation.

Improvements to the model and updated projections enhance policy decision making.

QUALITATIVE MODEL: Delphi Analysis

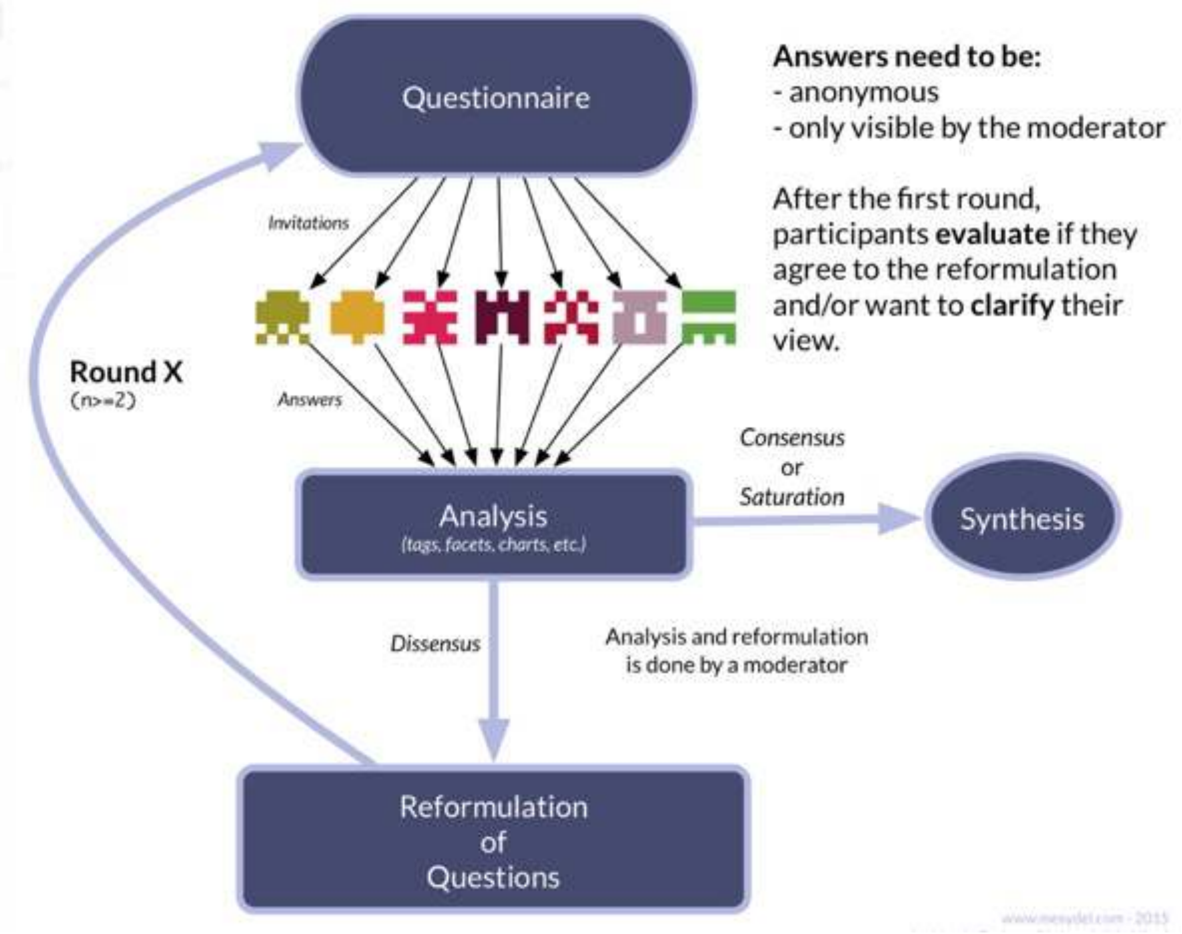
- **The Delphi method** consists of a multi-round survey to converge towards a common solution or view.

- At every round following the first one, the participants are given the results of the previous rounds.

- Thus, they are asked to reconsider their judgements based on the opinions of others.

- This helps them converge towards a common solution or view.

The Delphi Method



Source: Rivière, 2018

EXAMPLE

EurEnDel is the largest energy Delphi study that was ever conducted in Europe, with around 3,000 experts participating over a time frame of 30 years .

It aims to describe trends in the development of energy technologies, and to identify research and development needs in the energy sector.

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REFLECTION POINT

What do you think is the core contribution of qualitative models in the context of an IGE assessment?

QUALITATIVE MODEL: Causal Loop Diagram (CLD)

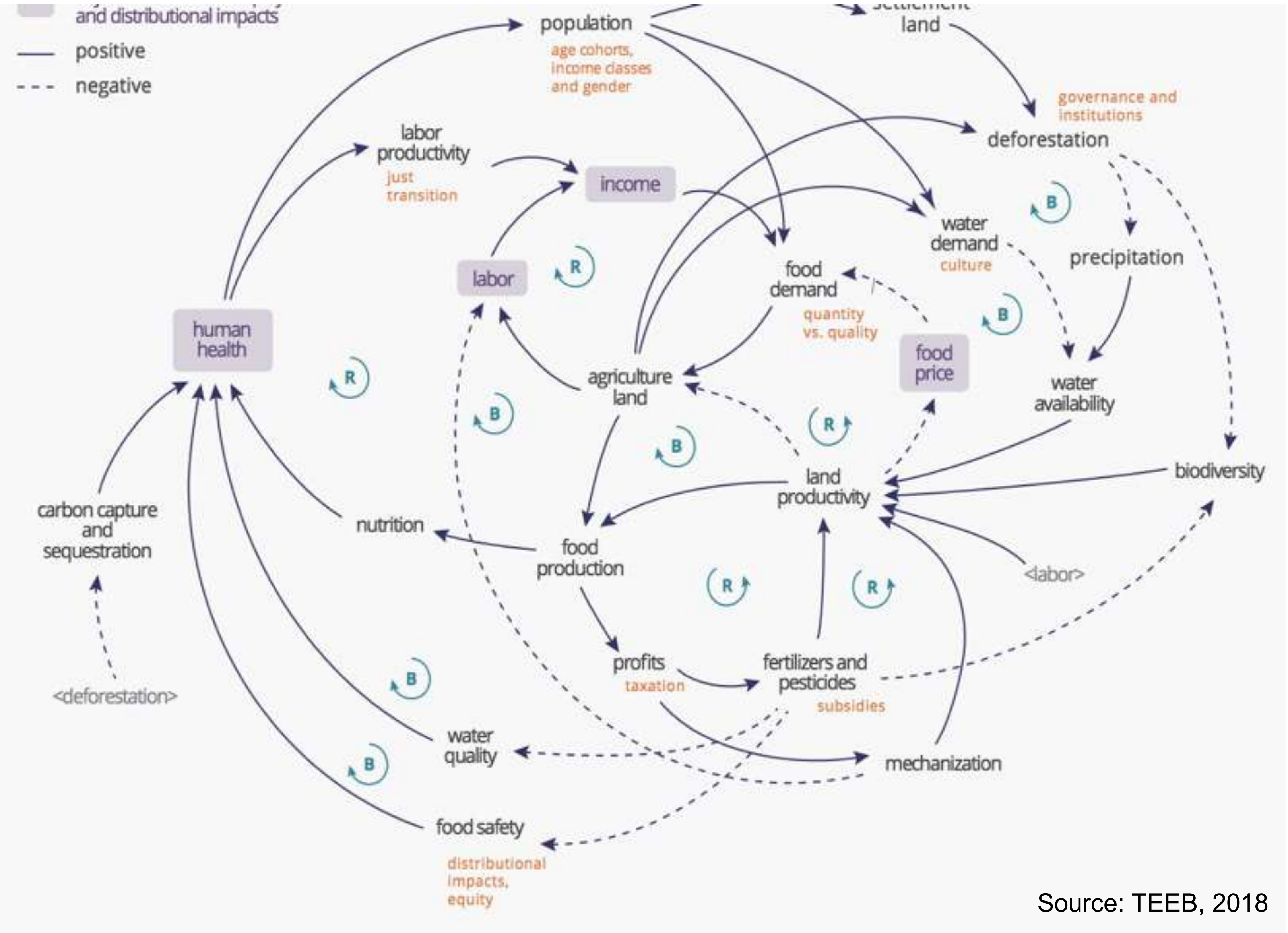
- A CLD consists of variables connected by arrows denoting the causal influences among the variables. Feedback loops are also identified in the diagram.
- CLDs support the identification of policy outcomes using a systemic approach.

EXAMPLE

CLDs have been used extensively to carry out qualitative assessments of policy impacts.

TEEB developed a CLD to explain the dynamics existing in the eco-agri-food system.

Illustrative Causal Loop Diagram of a generic eco-agri-food system (Source: Zhang et al. 2018)



Source: TEEB, 2018

REFLECTION POINT

What was your experience working with CLDs?

What do you think are the main strengths and weaknesses of CLDs?

QUANTITATIVE MODEL: Sectoral Input-Output (I-O) Tables

- Represent inputs and outputs of several economic activities, physical and/or monetary.
- An input-output model replaces the data in an input-output table with equations.
- I-O models can be descriptive and prescriptive.

I-O table in symbols

		Total domestic purchases of inputs							
		Agriculture	Manufacturing	Services	Household demand	Private investment	Government demand	Exports	Output (sales)
Industry by industry Total domestic production of outputs	Agriculture	O_{11}	O_{12}	O_{13}	C_1	I_1	G_1	EX_1	X_1
	Manufacturing	O_{21}	O_{22}	O_{23}	C_2	I_2	G_2	EX_2	X_2
	Services	O_{31}	O_{32}	O_{33}	C_3	I_3	G_3	EX_3	X_3
Gross value of output: IMPORT	Imports	M_1	M_2	M_3	M_C	M_I	M_G		M
Gross value of output: Gross value added	Taxes minus subsidy	T_1	T_2	T_3					T
	Wages and salaries	W_1	W_2	W_3					W
	Profit[1]	$Profit_1$	$Profit_2$	$Profit_3$					Profit
Total input (payment)		X_1	X_2	X_3	C	I	G	EX	
Employment by industry		E_1	E_2	E_3					
CO2 emissions by industry		$CO2_1$	$CO2_2$	$CO2_3$					

Source: ILO,2017

EXAMPLE

Cruz (2002) applied the I-O methodology to analyze energy flows and CO2 emissions in the Portuguese economy.

The I-O model distinguishes between energy demand by final consumers and direct and indirect energy requirements from industries.

Table 1 Primary Energy Intensities	Corresponding to Direct Production demand		+ Corresponding to Indirect Production demand		= Corresponding to Total Production demand		+ Corresponding to Direct Consumption Demand		= Corresponding to Final Demand			
	C		$C(A+A^2+...)$		$C(I-A)^{-1}$		P		**Total Primary Energy Intensity**		*Tt. Primary Energy Intensities' "Ranking"*	
unit: toe / million PTE	(1) coal	(2) oil	(3) coal	(4) oil	(5) coal	(6) oil	(7) coal	(8) oil	(9) coal	(10) oil	*coal*	*oil*
01 Agriculture, hunting and related service activit.	0.00	0.37	0.11	0.48	0.11	0.85	0.00	0.00	0.11	0.85	20	14
02 Forestry, logging and related service activities	0.00	0.23	0.02	0.09	0.02	0.32	0.00	0.00	0.02	0.32	36	26
03 Fishing and related service activities	0.00	1.05	0.03	0.28	0.03	1.34	0.00	0.00	0.03	1.34	34	9
04 Mining and manufacture of coal by-products	8.87	0.18	0.31	0.57	9.18	0.76	102.42	0.00	111.60	0.76	1	15
05 Extr. crude petroleum ..., and manuf. refined petroleum products	0.00	2.52	0.08	0.51	0.08	3.03	0.00	52.26	0.08	55.29	24	1
6A Fossil fuel electricity generation	9.13	12.60	0.07	0.24	9.20	12.85	0.00	0.00	9.20	12.85	2	2
6B Hydroelectricity	0.00	0.00	0.01	0.04	0.01	0.04	0.00	0.00	0.01	0.04	38	38
6C Electricity Distribution	0.00	0.00	4.16	5.82	4.16	5.82	0.00	0.00	4.16	5.82	3	5
07 Gas production and distribution	0.00	4.63	0.49	2.53	0.49	7.15	0.00	0.00	0.49	7.15	7	4
08 Water supply	0.00	0.00	0.73	1.04	0.73	1.04	0.00	0.00	0.73	1.04	6	12
09 Extraction and manuf. of ferrous and non-ferrous ores and metals	1.10	0.32	0.84	1.01	1.93	1.33	0.00	0.00	1.93	1.33	4	10
10 Extraction and manuf. of non-metallic minerals	0.96	0.78	0.47	0.95	1.43	1.73	0.00	0.00	1.43	1.73	5	8
11 Manuf. of chemicals and chemical products	0.02	1.95	0.18	0.61	0.20	2.55	0.00	0.00	0.20	2.55	13	6
12 Manufacture of fabricated metal products	0.00	0.06	0.32	0.58	0.32	0.64	0.00	0.00	0.32	0.64	9	20

Source: Cruz, 2002

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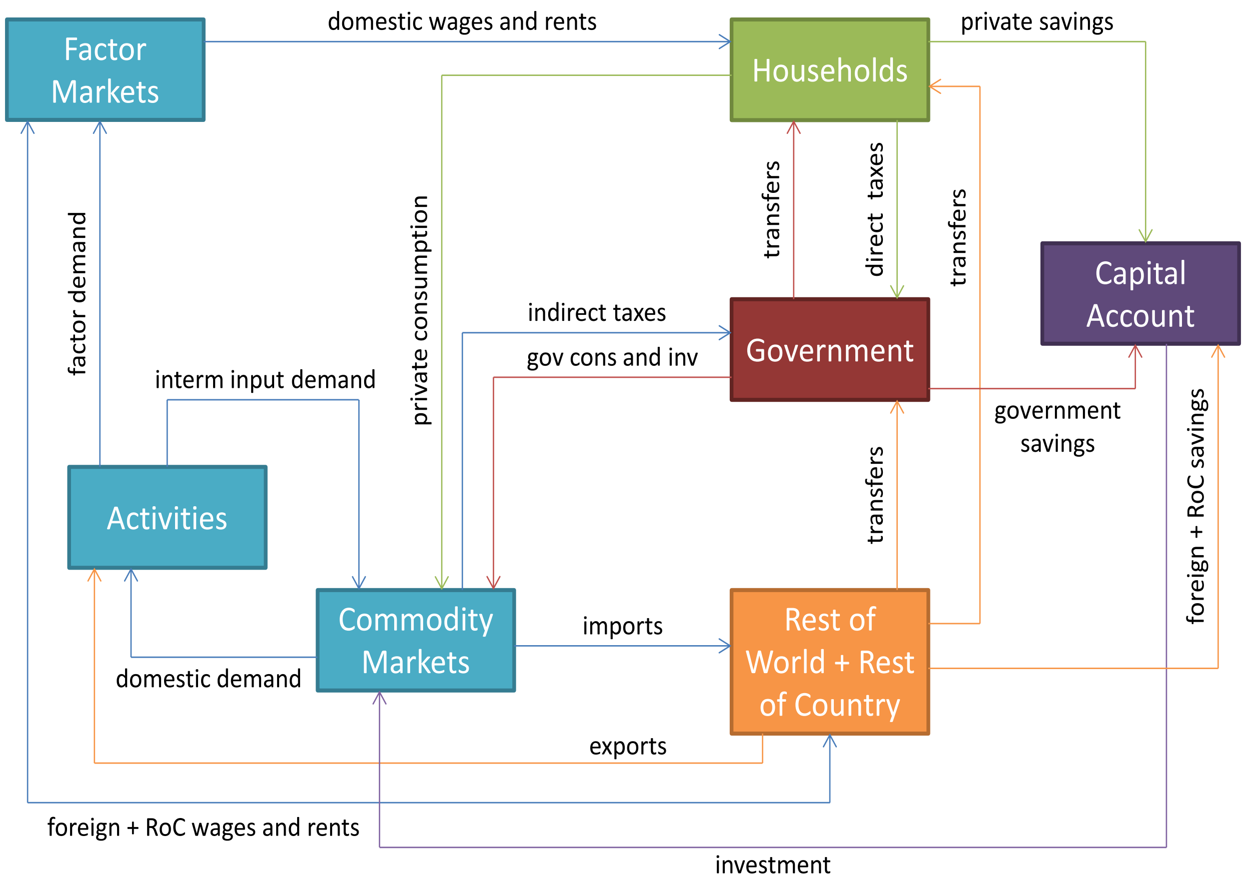
REFLECTION POINT

What do you think is the most useful application of I-O models?

Sectoral level (e.g. for industries) or macroeconomic?

QUANTITATIVE MODEL: Computable General Equilibrium (CGE)

- Models supply and demand behaviour across all markets in an economy.
- Widely used to analyse the aggregate welfare and distributional impacts of policies.
- Optimize the benefits for various economic actors.



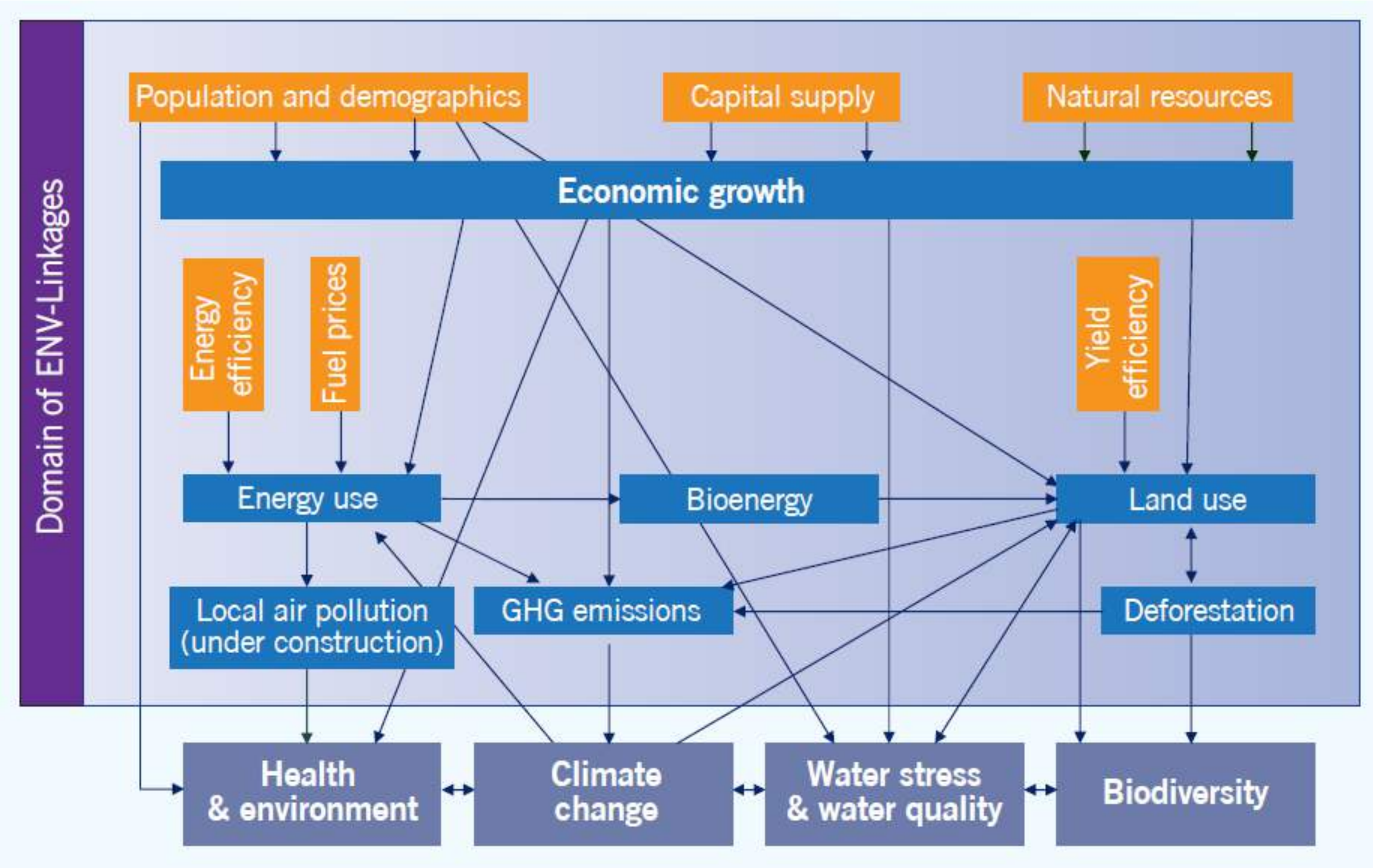
Source: Banerjee, Onil, 2019.

EXAMPLE

The ENV-Linkages model is a multi-sectoral and multi-regional dynamic CGE model, based on microeconomic foundations.

It is used to generate the results for the OECD Environment Outlook to 2050.

It uses the Global Trade Analysis Project (GTAP) as data input.



Source: OECD, 2012.

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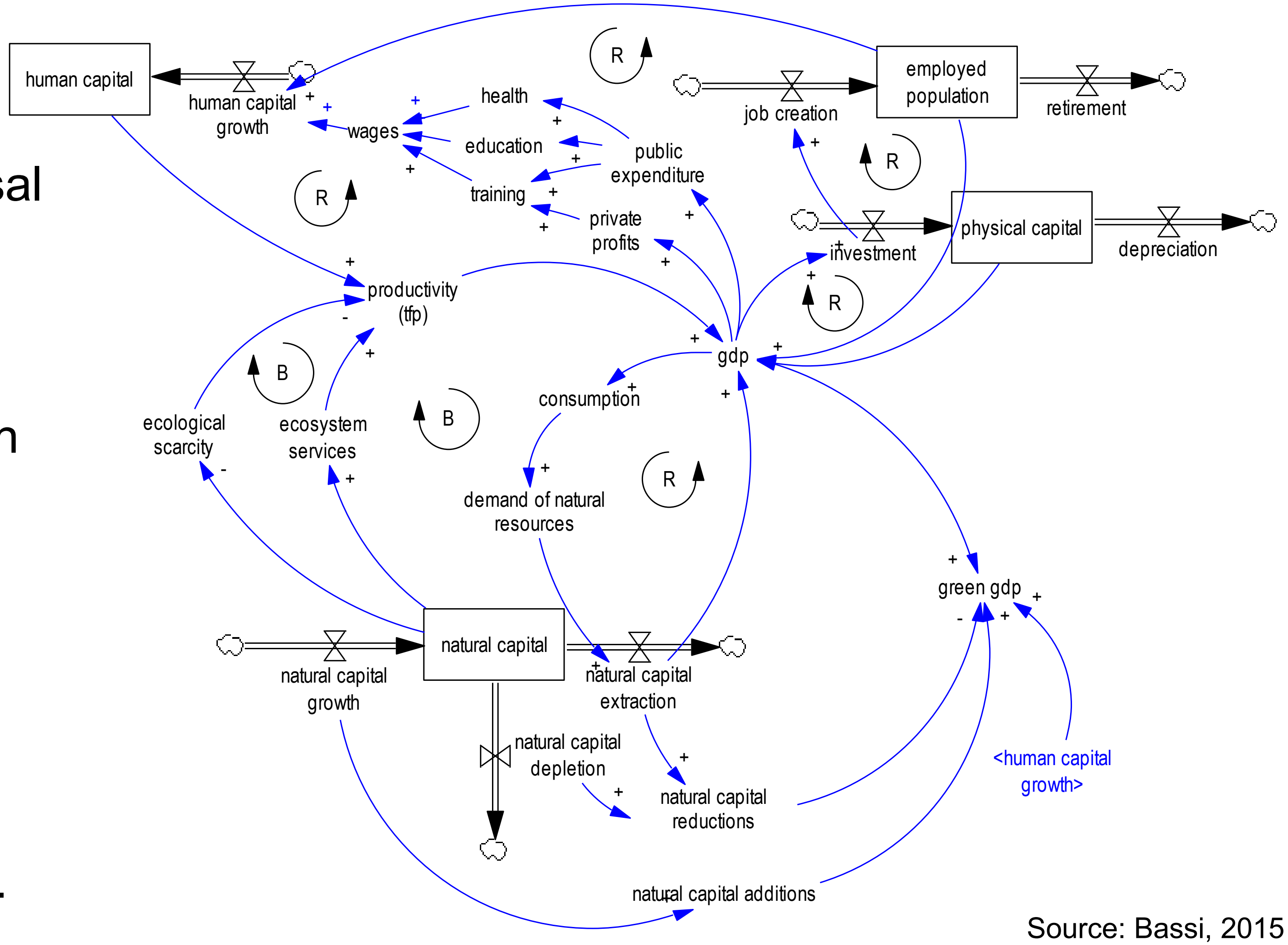
REFLECTION POINT

The concept of equilibrium is frequently debated.

To what extent do you see it as a realistic assumption for economic models?

QUANTITATIVE MODEL: System Dynamics

- Integrated quantitative approach (causal descriptive) utilized to understand situations for complex issues.
- Methodology that allows the integration of social, economic and environmental indicators.
- The pillars are feedback, delays and non-linearity.
- Models can be top-down or bottom-up.

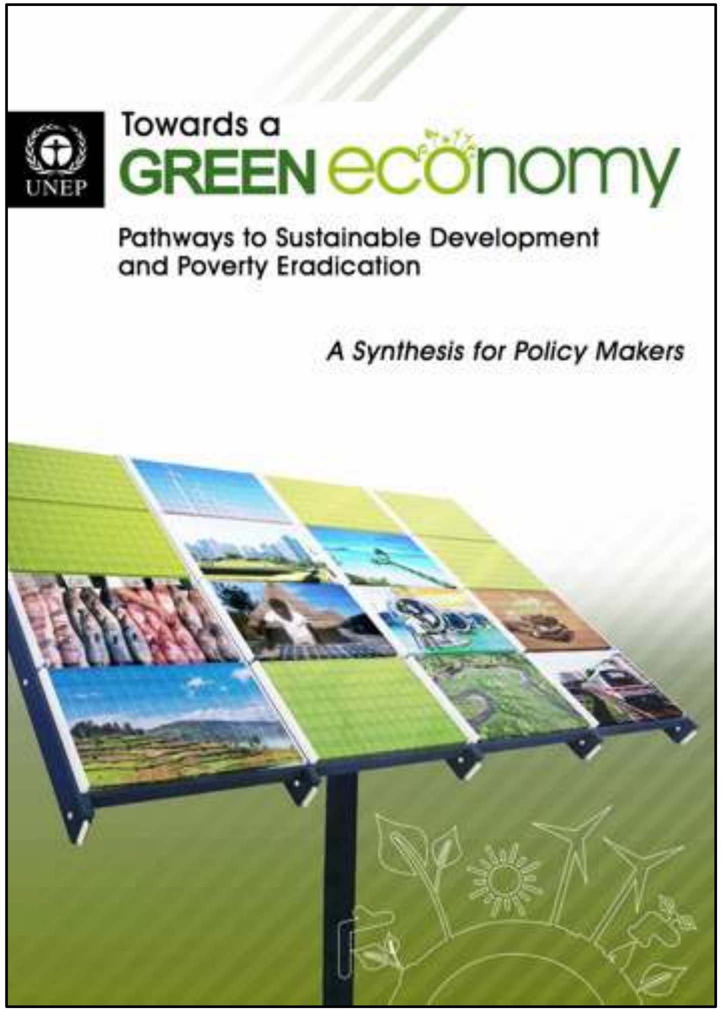


Source: Bassi, 2015

EXAMPLE

- The model developed for the Green Economy Report is a System Dynamics model that largely draws upon the Threshold 21 family of models.
- It integrates variables and data at the macro level, while allowing for sectoral disaggregation.
- Simulates the main short-, medium- and longer-term impacts of investing in a green economy.

UNEP Green Economy Report

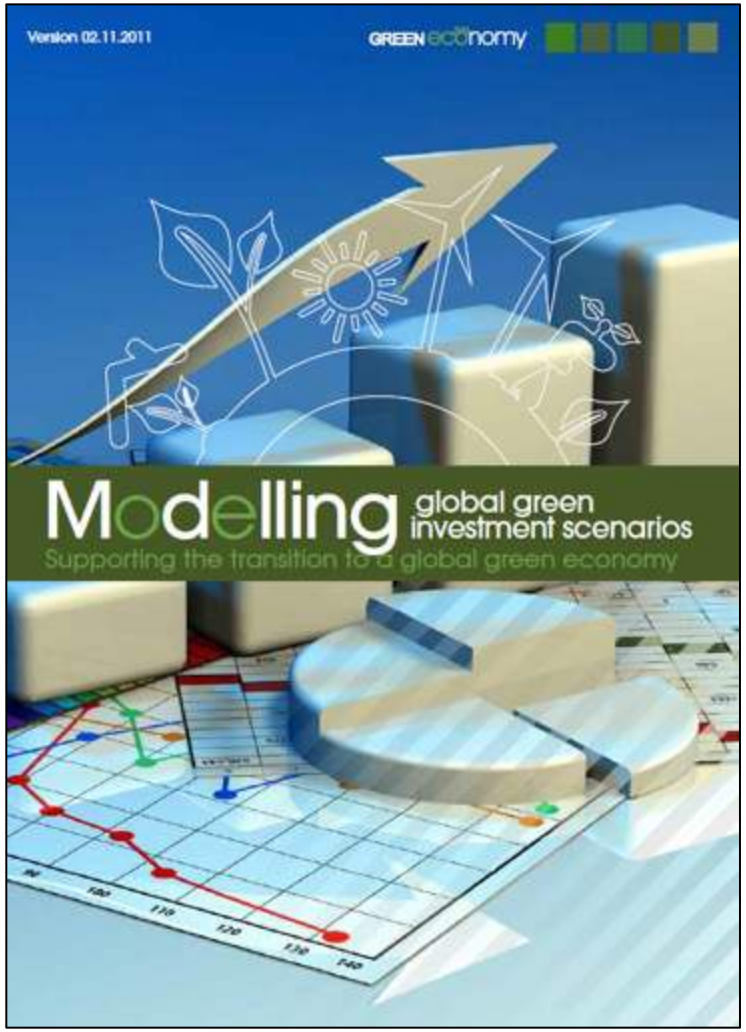


Source: UNEP, 2011

GLOBAL GREEN ECONOMY MODELLING WITH SYSTEM DYNAMICS

- An attempt to shed light on the benefits of Green Economy interventions at the global level.
- First modelling exercise of this kind, using a systems approach in a GE context.

UNEP Global Green Investment Scenarios



Source: UNEP, 2012

POLL

System Dynamics has been used very often for IGE, Circular Economy and Climate Adaptation assessments. Why?

A. Highly standardized approach and model.

B. Strong stakeholder engagement to conceptualize and create the model, creating local ownership.

C. Useful method for “knowledge integration”, which allows to better represent the IGE concept in a model.

COMPLEMENTARITY IS CRITICAL FOR MODELLING USEFULNESS

A transition to an Inclusive Green Economy requires a combination of policy interventions with crosscutting impacts.

Complementarity strengthens the analysis and addresses some of the weaknesses of each methodology with inputs from others.

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3 Interpretation of Model Results

REFLECTION POINT: How the underlying method influences model results

Do you remember what the three methods were?

How do you think they influence the results of a model?

HOW THE UNDERLYING METHOD INFLUENCES MODEL RESULTS

Static models

- Tend to overestimate policy impacts (lack of feedback).
- These include I-O (e.g. SAM) and linear models.

Optimization models

- Tend to underestimate policy impacts (when producing a snapshot).
- These include CGE models, energy optimization models.

Dynamic models

- Capture short-term impacts (otherwise seen as possible overestimate).
- Capture medium to longer term impacts (otherwise seen as possible underestimate).

EXAMPLE: MODELLING THE IMPACTS OF SUBSIDY REFORM

Problem statement:
Is keeping subsidies inefficient and costs too much?

1. Fossil fuel subsidy removal increases energy prices.

2. 100% reallocation of subsidy savings improves all key indicators relative to business as usual (BAU), but it does not reduce public deficit.

Fossil fuel subsidies in Thailand: trends, impacts, and reforms.

Source: ADB, 2015

EXAMPLE: MODELLING THE IMPACTS OF SUBSIDY REFORM

Problem statement:
Who will be impacted if we remove subsidies?

3. No compensation has negative impacts on all households, but it reduces emissions and lowers public deficit.

Problem statement:
What are the impacts of providing compensation?

4. Reallocation to all households shows generally better impacts than compensating only the bottom 40%, but it is not as effective in lowering public deficit.

MODELLING APPROACH

Three groups of models used:

Social Accounting Matrix (SAM) for short-term economic impacts (static assessment), including detailed distributions analysis;

CGE and macroeconometric model for assessing macroeconomic impacts, short, medium and longer term;

MARKAL models for assessing impacts for the energy sector.

Sectoral and geographically disaggregated impact analysis for households (e.g., savings).

Reallocation of funding. Distributional effects and opportunities.

Economic flows across the key actors of the economy.

SAM

Social Accounting Matrix

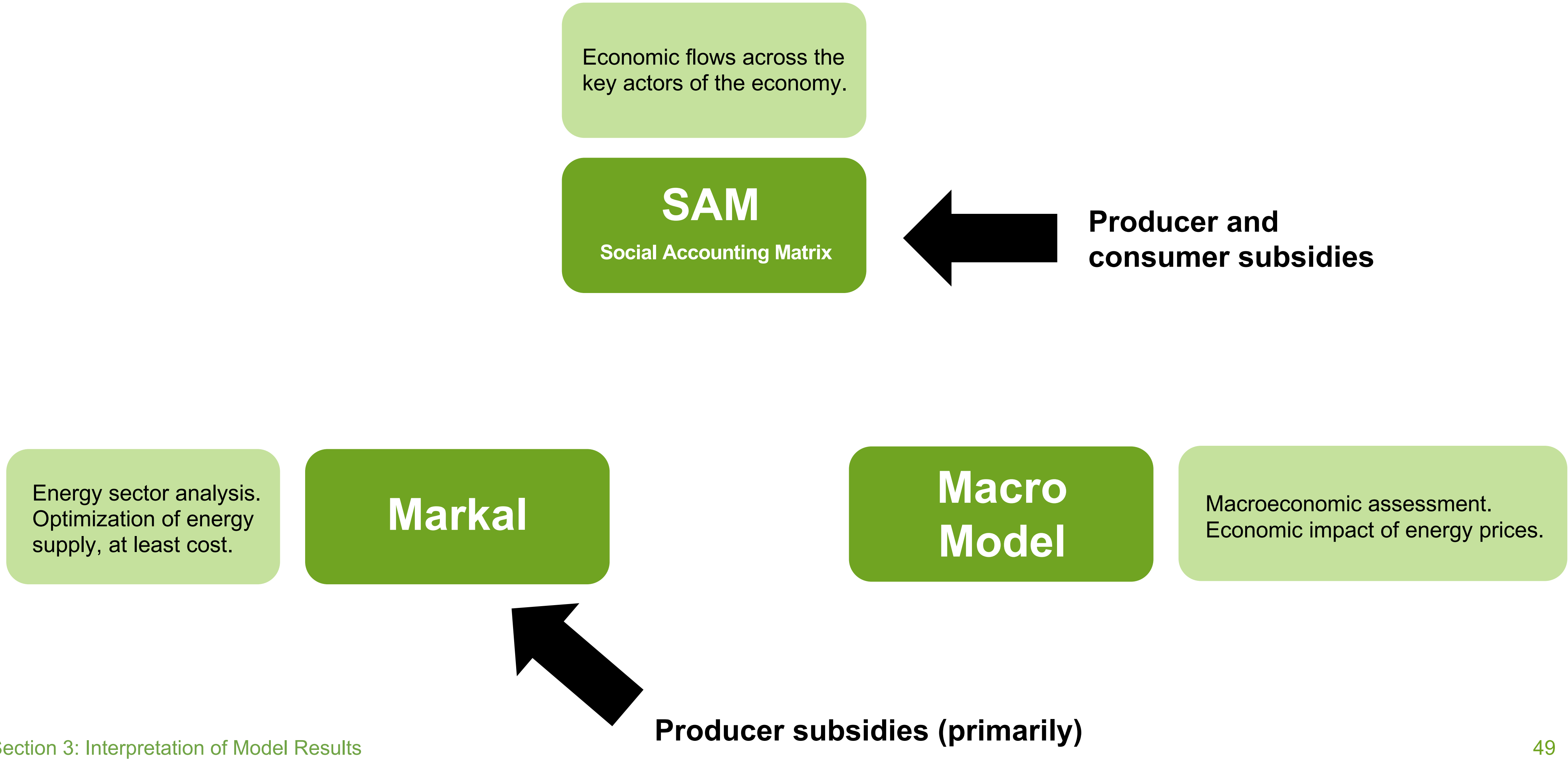
Energy sector analysis. Optimization of energy supply, at least cost.

Markal

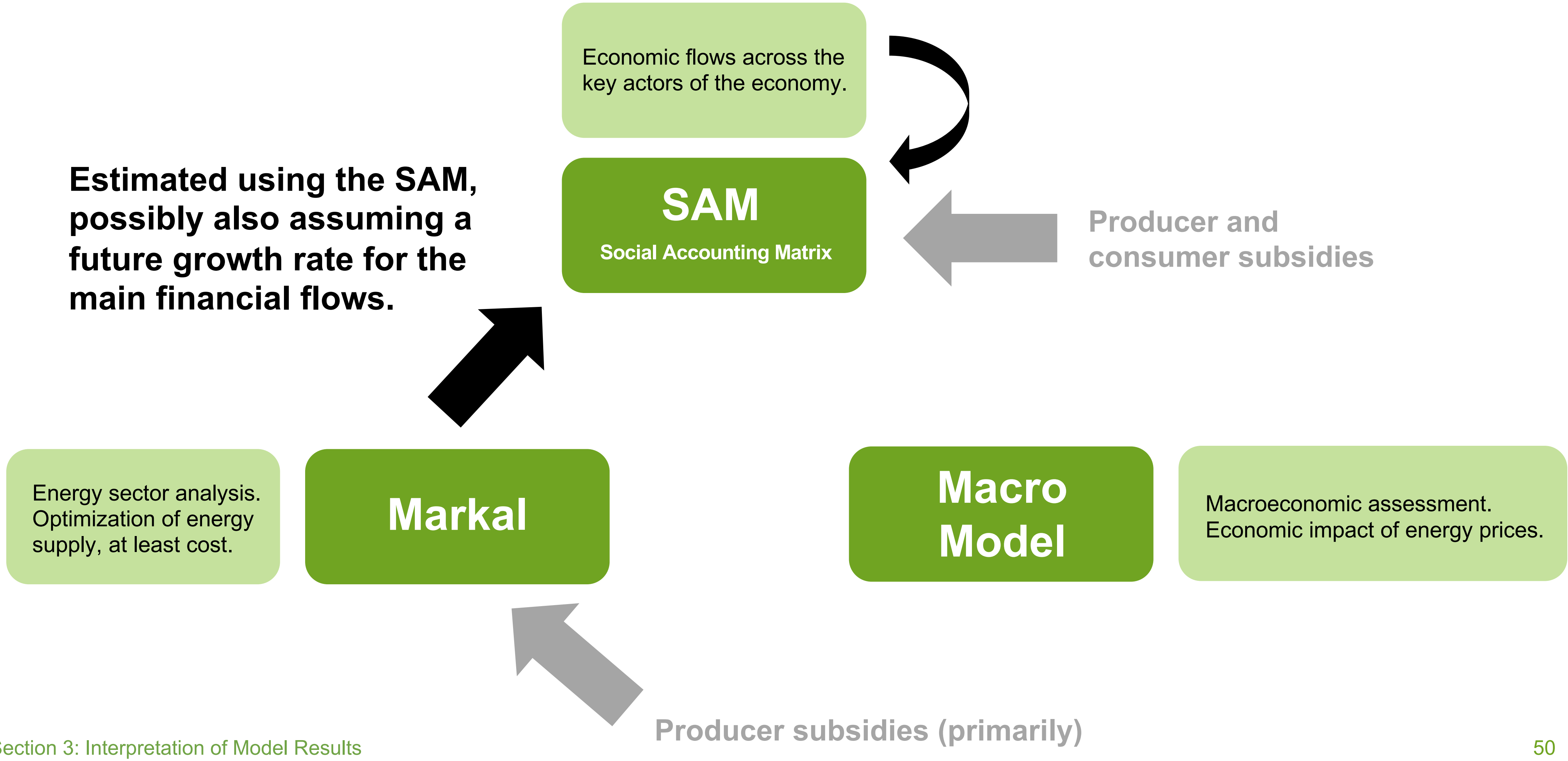
Macro Model

Macroeconomic assessment. Economic impact of energy prices.

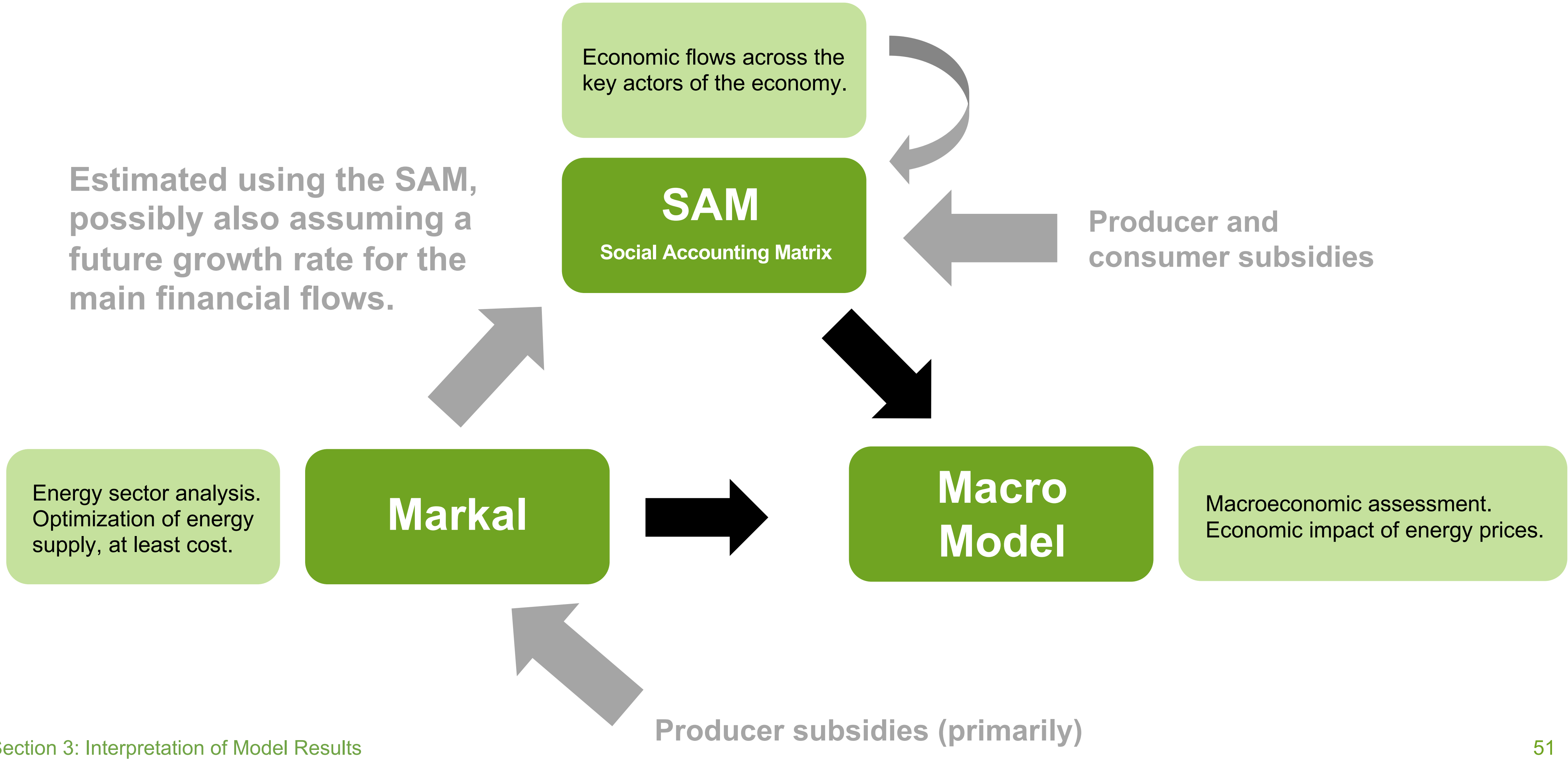
DIRECT IMPACTS

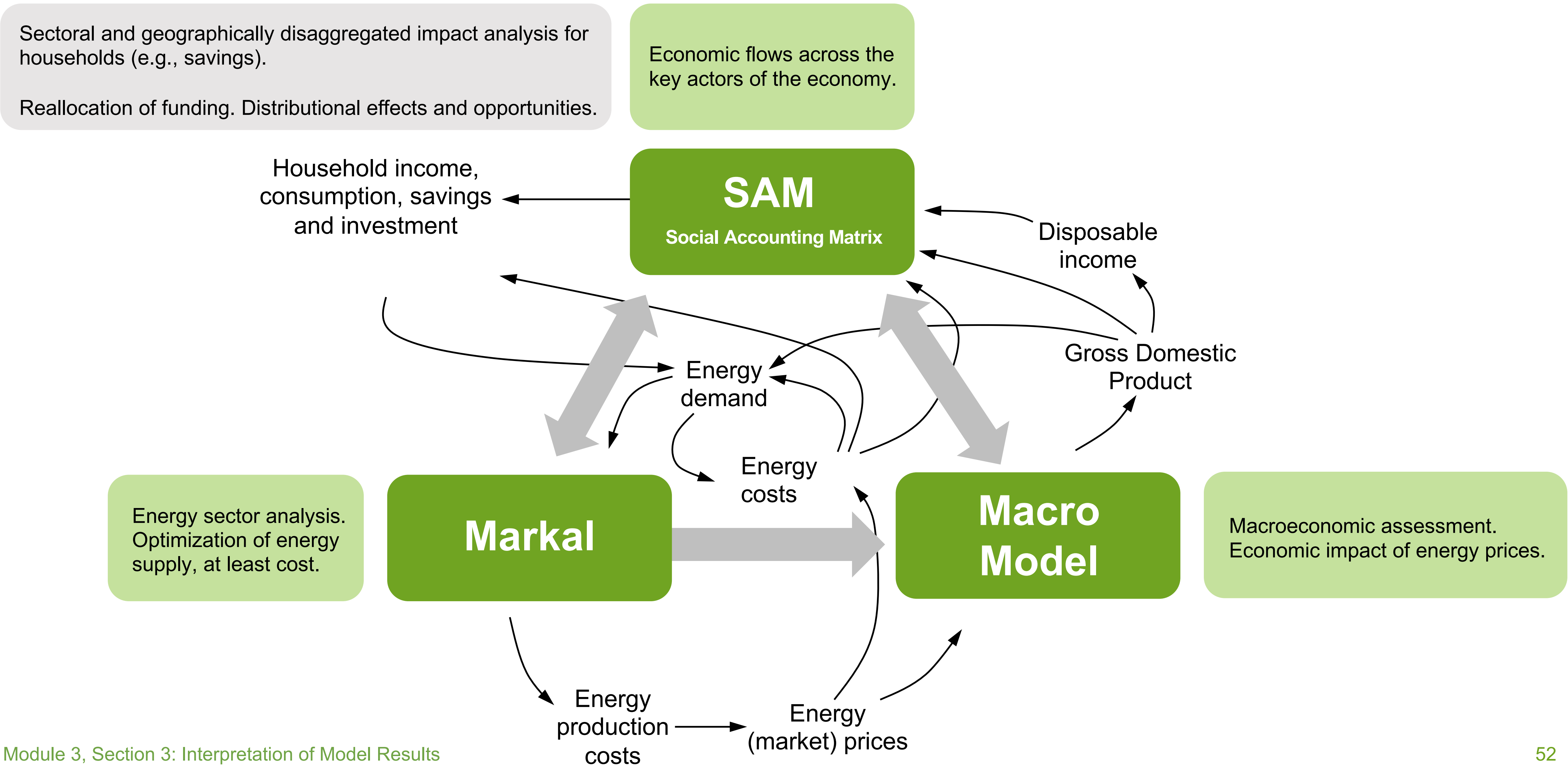


INDIRECT IMPACTS



INDUCED IMPACTS




Sectoral and geographically disaggregated impact analysis for households (e.g., savings).
Reallocation of funding. Distributional effects and opportunities.
Economic flows across the key actors of the economy.
Household income, consumption, savings and investment
SAM
Social Accounting Matrix
Disposable income
Energy demand
Gross Domestic Product
Energy costs
Energy sector analysis. Optimization of energy supply, at least cost.
Markal
Macro Model
Macroeconomic assessment. Economic impact of energy prices.
Energy production costs
Energy (market) prices

MAIN CHARACTERISTICS OF THE MODELS CHOSEN – INDIA EXAMPLE

Model	Base year	Household and sectoral disaggregation	Energy sources	Impacts modelled	Reallocation assumptions
India					
SAM	2007-08 with subsidy adjustment	5 rural and 4 urban (employment-based) household groups; 78 economic sectors.	Oil, gas, coal and electricity.	Direct and indirect	Compensation to households and reallocation to government budget
MARKAL	2011	Rural and urban households; residential, commercial, industrial (with energy-intensive manufacturing sectors) and transport.	Detailed primary and secondary energy supply.	Direct	No compensation and reallocation
E3MG	2011	42 economic sectors, 5 rural and 4 urban (employment-based) household groups	Primary and secondary energy supply (22 different users of 12 different fuel types).	Direct	Compensation to households and budget/deficit reduction

Comparative assessment of results

		India	Indonesia	Thailand
SAM: Short-term (2012), full compensation to all HH, remainder to gov. expenditure	GDP	-0.4	-1.3	2.02
Macro: Long-term (2020), compensation to all HH, remainder to gov. deficit	GDP	0.04	-0.09	-1
	% change in CPI	0.58	3.15	-1

Comparative assessment of results

		India	Indonesia	Thailand
MARKAL long-term ~2030	GHG emissions (% change)	-1.8	-5.1%	-2.8%
E3MG long-term ~2030	GHG emissions (% change)	-1.3	-9.3%	n/a

REFLECTION POINT

When asked to perform a policy assessment, do you begin with:

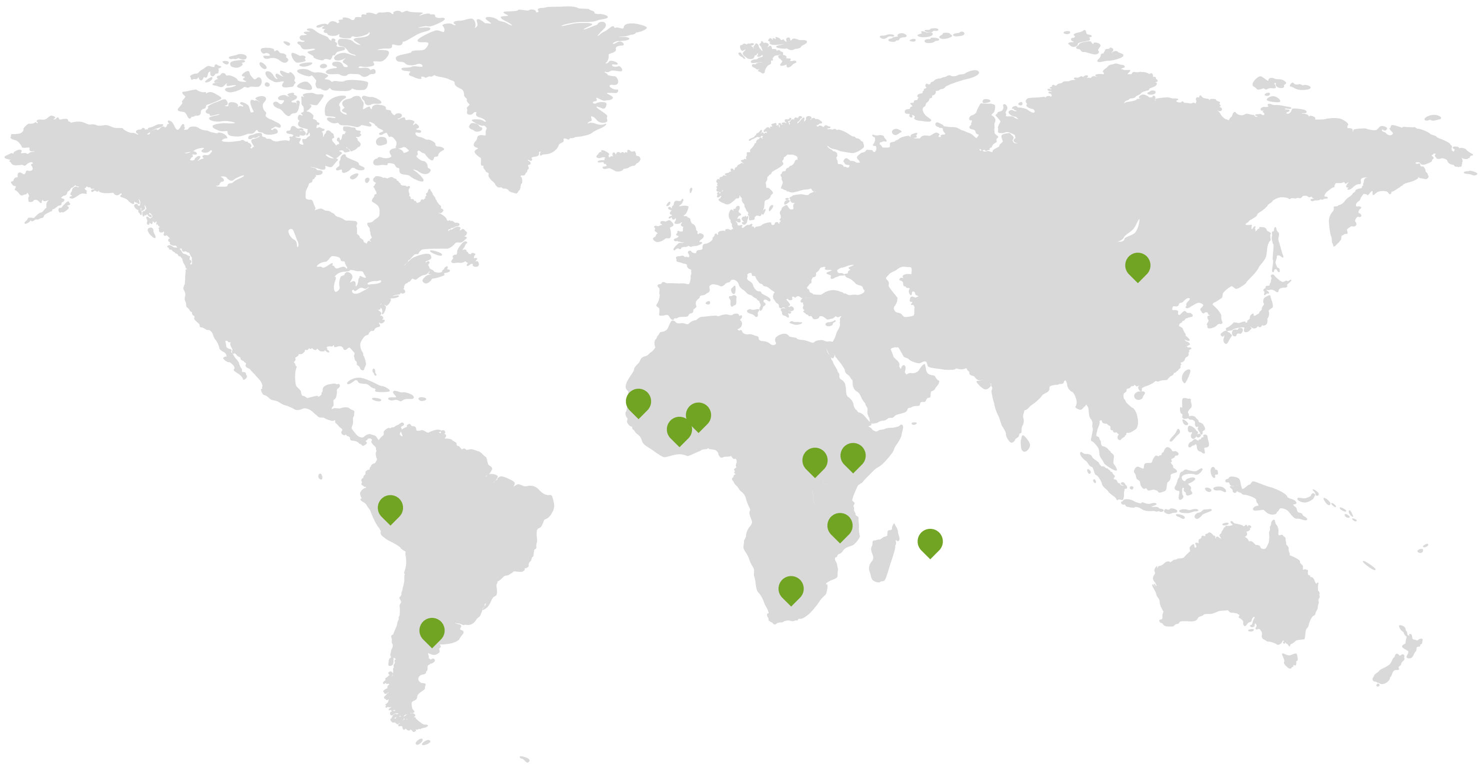
1. What model can I use?

2. How can I adapt my model?

4 In depth review: Integrated Green Economy Modelling (IGEM) framework

BACKGROUND

- Since the launch of the Green Economy Report (GER) in 2011, UNEP has supported countries in developing Green Economy Policy Assessments (GEPAs).
- GEPAs have been carried out in South Africa, Kenya, Rwanda, Senegal, Burkina Faso, Uruguay, Ghana, Mauritius, Mozambique, Peru, and Mongolia.

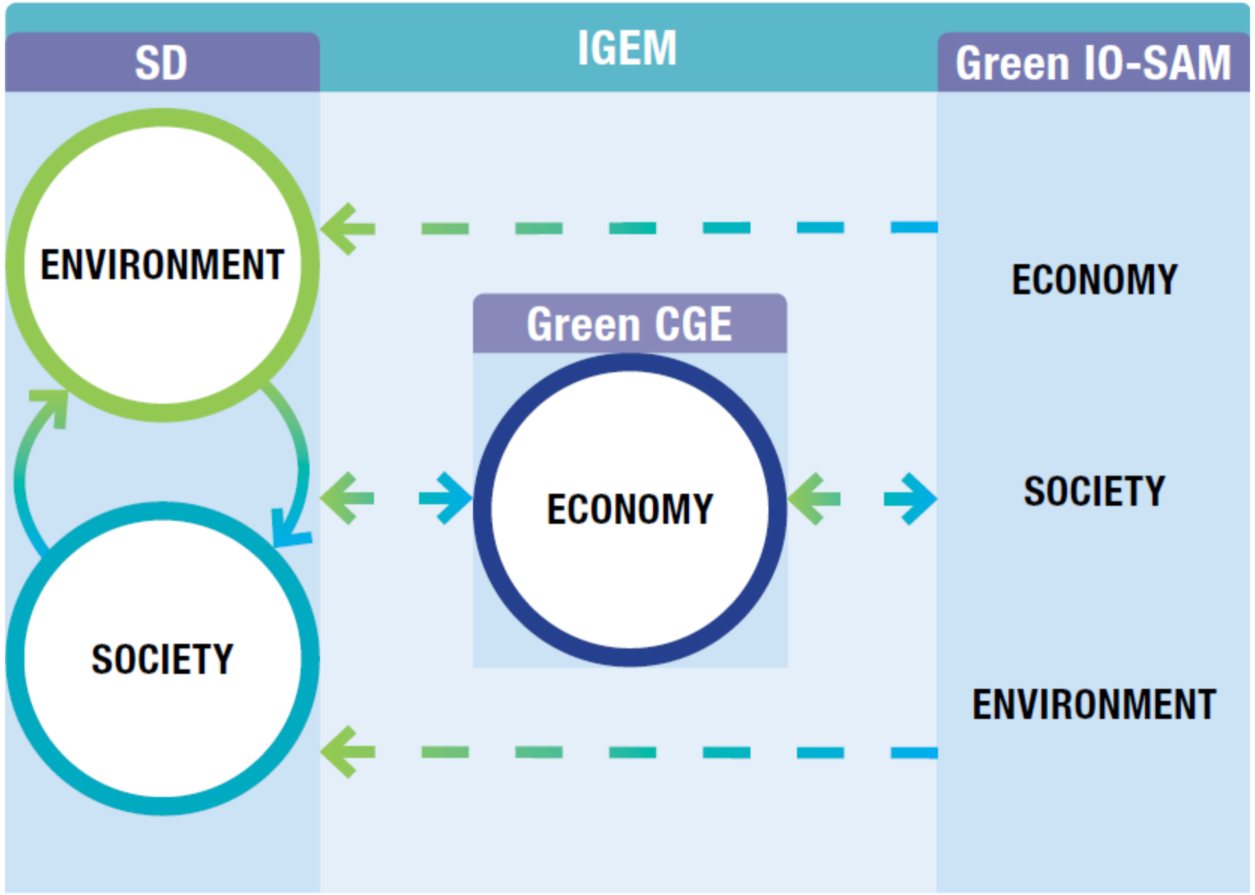


WHAT IS THE IGEM FRAMEWORK?

The **Integrated Green Economy Modelling (IGEM)** was designed to:

- Answer increasingly complex requests from governments;
- Support countries with solid quantitative tools to inform the design and implementation of green economy policies;
- Advance the process of implementing and monitoring some of the Sustainable Development Goals (SDGs).

DIAGRAM OF THE IGEM FRAMEWORK SHOWING THE LINKAGES BETWEEN THE SD, CGE AND I-O SAM MODELS



Source: PAGE, 2017

GREEN CGE AND GREEN I-O SAM

Diagram of the linkages between the CGE model and the I-O SAM model

Source: PAGE, 2017

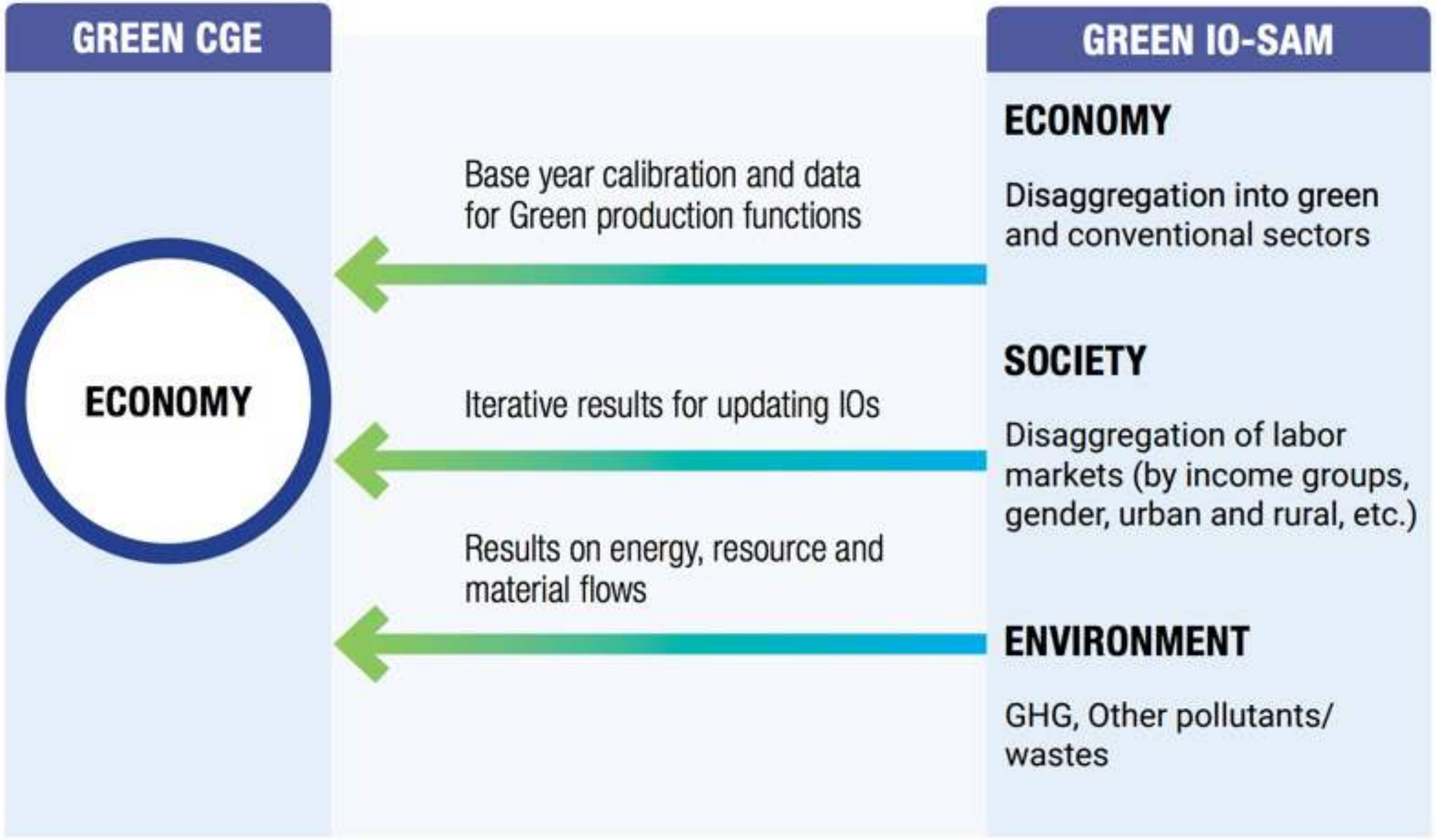
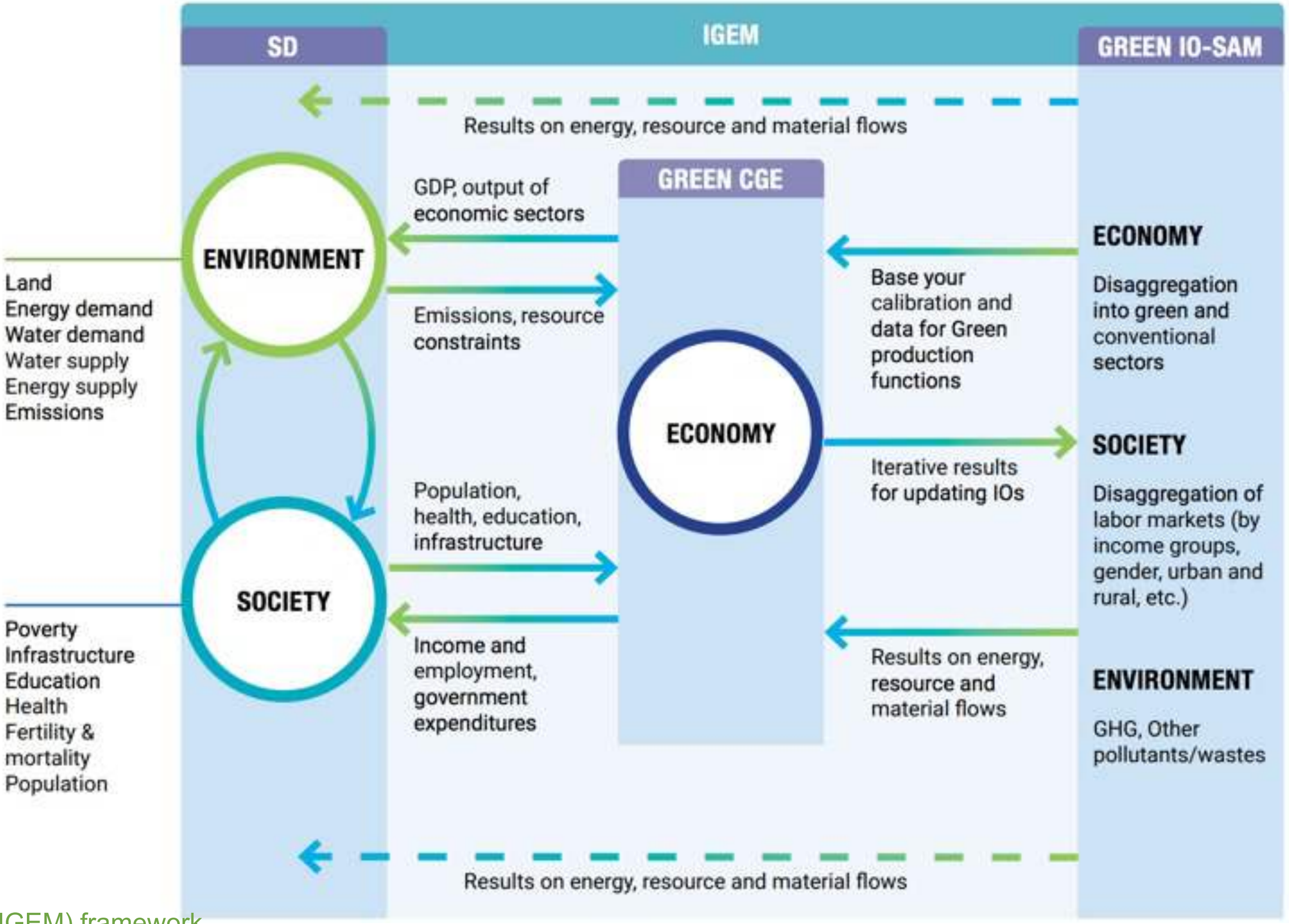


DIAGRAM OF IGEM FRAMEWORK INFORMATION STRUCTURE

Diagram of the IGEM framework information structure

Source: PAGE, 2017



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TARGETS VERSUS INVESTMENT DRIVEN

The IGEM can be applied in two ways to analyse green economy policies:

following a **target-driven** approach;

x

following an **investment-driven** approach.

TARGET-DRIVEN APPROACH

GREEN CGE

2) Translate emission target into an "Avoided cost of pollution" (e.g. estimated price or shadow price of an avoided metric tonne of CO_2)

3) Calculate different tax rates to be applied to the energy sector, using extensions to the model from IO and SAM

4b) Look at impacts in other sectors of the CGE model following the implementation of the carbon tax (redistribution of tax revenues, production, trade, employment effects, etc.)

(1)

(2)

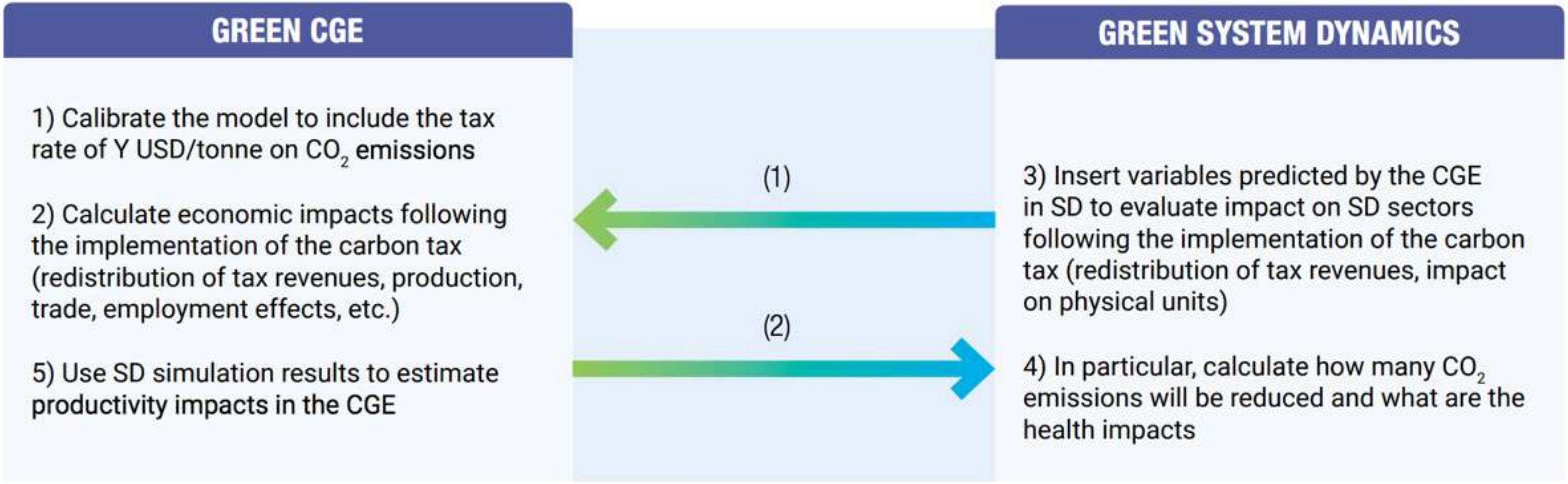
GREEN SYSTEM DYNAMICS

1) Target: Reduction in CO_2 emissions

4a) Look at impacts in other sectors of the SD model following the implementation of the carbon tax (redistribution of tax revenues, impact on physical units, e.g. on emissions and health)

Source: PAGE, 2017

INVESTMENT- (OR PRICE-) DRIVEN APPROACH



Source: PAGE, 2017

CARBON TAX SCENARIOS TESTED BY THE IGEM FRAMEWORK

<table>
<tr><th>SCENARIO</th><th>TAX RATE</th><th>CGE</th><th>SYSTEM DYNAMICS</th></tr>
<tr><td>Scenario 1 - Feebate scenario with low tax rate (FBL)</td><td>3.5 USD/tCO_2eq (current carbon tax rate in Mexico)</td><td rowspan="5">1) Estimate the economic effects of feebate scenarios compared to a revenue neutral carbon tax (lump-sum) and a business-as-usual scenario

3) Use results from the SD to estimate effects of increased longevity on productivity</td><td rowspan="5">2) Estimate the social and environmental impacts resulting from the CGE simulation (health and emissions)</td></tr>
<tr><td>Scenario 2 - Feebate scenario with high tax rate (FBH)</td><td>25 USD/tCO_2eq[40]</td></tr>
<tr><td colspan="2">The two feebate scenarios will be compared to:</td></tr>
<tr><td>Rebate scenario (lump sum) with high (RH) and low (RL) tax rates</td><td>3.5 and 25 USD/tCO_2eq</td></tr>
<tr><td>Business-as-usual scenario (BAU)</td><td>No carbon tax[41]</td></tr>
</table>

Source: PAGE, 2017

CONCLUSIONS – on Greening

The **IGEM framework** shows:

The CGE can be greened through the inclusion of additional sectors and/or by using a green I-O SAM as input;

The SD model can be greened by disaggregating a particular sector to address environmental and social questions of interest to policymakers.

CONCLUSIONS – on Coupling

- The IGEM framework identifies the main entry points between the models and how this linkage can be reinforced following different rounds of integration.

- In Mexico, GDP growth is enhanced when the effect of lower emissions on longevity and, later, on labor productivity is taken into account. Linkages go in both directions (CGE ⟷ SD)

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

End of Module 3.

Thank you for your attention!

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Annex A

Additional Information About Different Models

QUANTITATIVE MODEL: Social Accounting Matrix (SAM)

- A comprehensive, economy-wide input-output table with details of all transactions that have taken place between economic agents in an economy.
- A SAM displays the macro- and meso-economic accounts of a socio-economic system in a square matrix, ensuring that all inflows equal the sum of the outflows.
- The SAM can be regarded as an extension of an I-O table.

EXAMPLE

- SAM analysis for evaluating renewable energy initiatives in Egypt.
- The analysis aimed at examining what initiatives would yield the highest benefits for Egypt, for GDP and household income.

Type of Multiplier	Multiplier of base scenario (current level of investment)	Multipliers of 1st scenario (DESERTEC plan)	Multipliers of 2nd scenario (secure local demand of electricity from CSP)	Multipliers of 3rd scenario (government plan till 2020)
GDP multiplier	1.62	2.12	1.67	1.72
Income multiplier	2.15	2.19	2.04	2.16
Output Multiplier	4.04	4.32	4.46	4.21

Source: Farag and Komendantova, 2014

Annex B:
Additional information about IGEM

EXAMPLE OF RESULTS FROM THE IGEM

- The IGEM simulated the dynamic CGE model in conjunction with the SD model, and used output gathered from the SD model to supplement and adjust the CGE input parameters.
- It is estimated that a carbon tax would have positive impacts on the health of the population and labor productivity.
- As a result, IGEM considers **any increase in longevity equal to an increase in productivity.**

RESULTS FROM THE IGEM

Aggregate and sectoral effects of a revenue-neutral carbon tax and a feebate scenarios, in 2036.

Source: PAGE, 2017

	COLUMN 1	COLUMN 2	COLUMN 3
	RH with longevity vs BAU (%)	RH with longevity vs RH no longevity (%)	RH with longevity vs RH with no longevity (%)
GDP	-2.5608	0.3332	1.2949
Investment	-2.7583	0.7796	3.8981
Government[57]	-1.3718	0.1916	0.3705
Capital Stock	-2.0615	0.2945	1.7113
Welfare			
Agent 1 (20% poorest)	-0.5612	0.0614	0.0709
Agent 2 (3-5 deciles)	-0.8088	0.0585	0.0938
Agent 3 (6-8 deciles)	0.0525	0.0525	0.1438
Agent 4 (20% richest)	-1.1663	0.0533	0.2468
Aggregate welfare agents 1-4	-0.9912	0.0545	0.1786
Government welfare	0.0583	0.0542	0.0471
Selected sectors			
Agriculture	-2.2540	0.5032	0.4238
Manufacturing	-3.3250	0.7797	0.5180
Oil	-19.4086	0.3080	-1.4591
Natural gas	-18.6950	0.3195	-1.2141
Mining	-48.2412	0.2921	0.0974
Refining	-16.7771	0.3899	-0.1950
Electricity	-5.8425	0.4676	23.7461

SUMMARY OF RESULTS FROM THE IGEM

SCENARIO	MAIN RESULTS FROM CGE SIMULATION	MAIN RESULTS FROM SD SIMULATION	MAIN RESULTS FROM IGEM SIMULATION (SD-CGE)
— Scenario 1 – Feebate scenario with low tax rate (FBL) — Scenario 2 – Feebate scenario with high tax rate (FBH) The two feebate scenarios will be compared to: — Rebate scenario (lump sum) with high (RH) and low (RL) tax rates — Business-as-usual scenario (BAU) = no carbon tax	Scenario 1: FBL-BAU — Introducing a carbon tax on emissions of fossil fuels will entail small losses with regards to consumer welfare, GDP, and the size of the capital stock. Scenario 2: FBH-RH — Feebate scenario will result in higher values for aggregate indicators (e.g. GDP, Investment, etc.) up to 2036 than rebate scenario. Both scenarios — A carbon tax paired with "green" investment will have positive environmental impacts, while improving the energy mix by increasing the share of renewables with minimal impact on overall production (GDP).	Scenario 1: FBL-BAU/RL — Low tax levels are of limited capacity in inducing a transformation of the electricity generation mix. Scenario 2: FBH-BAU/RH — Feebate policy, with the high carbon tax on full emissions, achieves the greatest carbon emission reduction.	— GDP grows up to 1.3 percentage points (0.33 percentage points) when the effect of lower emissions on longevity and later on labour productivity is taken into account in the feebate (rebate) scenario. — The gains are more or less evenly distributed over all consumers, with a slight bias towards the richest agents in the economy. — Government revenues also increase.

Source: PAGE, 2017