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# INTEGRATED GREEN ECONOMY MODELLING (IGEM) FOR REFINED POLICY IMPACT ANALYSIS

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# UN ENVIRONMENT COUNTRY EXPERIENCE WITH GREEN ECONOMY MODELLING

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## 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.
- With the exceptions of Mauritius and Mozambique, the Threshold 21 (T21) model was employed.
  - The T21 model is a system dynamics model that includes endogenous links within and across the economic, social and environmental sectors through various feedback loops.

# THE INTEGRATED GREEN ECONOMY MODELLING (IGEM) FRAMEWORK

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# WHAT IS THE IGEM FRAMEWORK?

The Integrated Green Economy Modelling (IGEM) framework aims to integrate 3 of the modelling techniques to refine impact analysis of green policies and investments in the economy. It was designed to:

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

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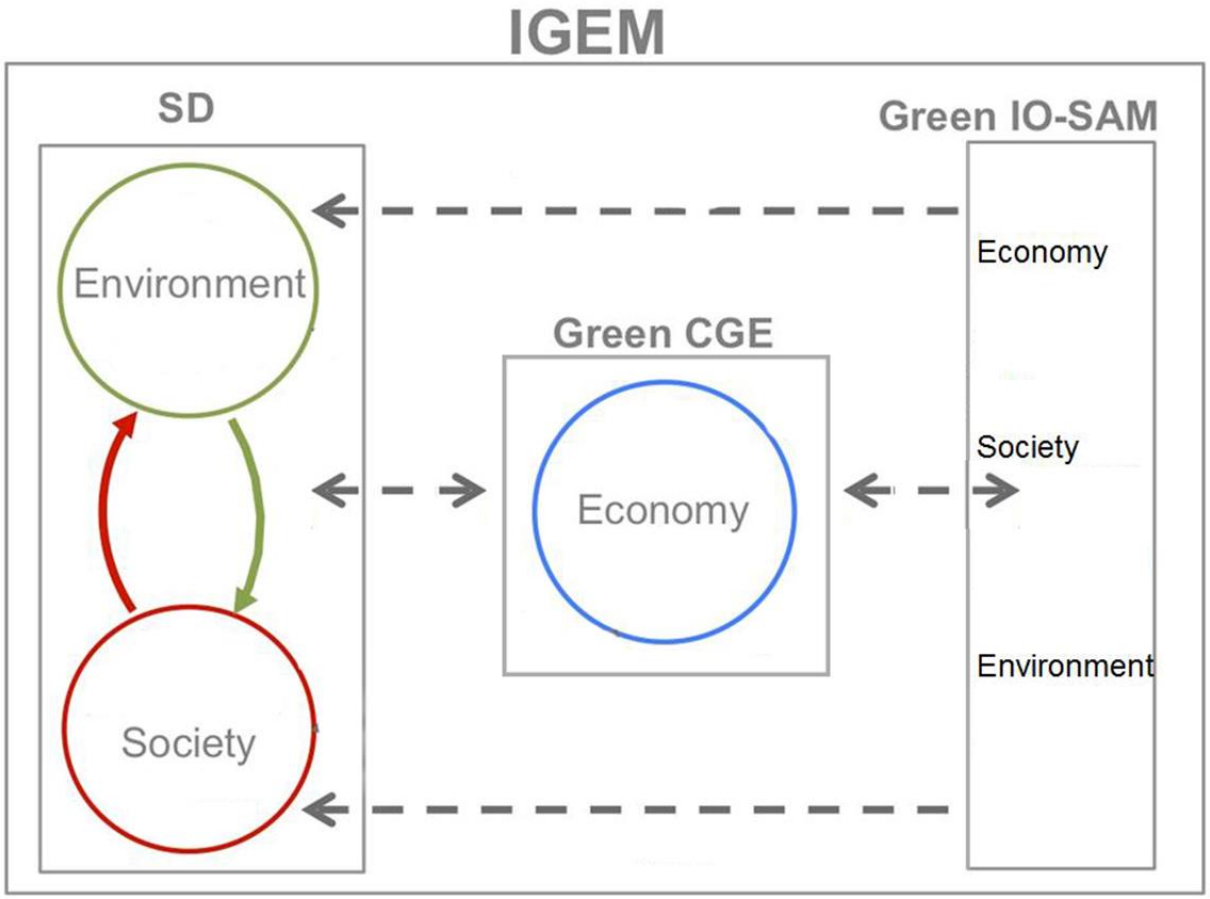
# FROM THE T21 TO THE IGEM FRAMEWORK

- The IGEM framework methodology explores how different modelling tools could complement each other to enrich the analysis and expand the set of policy questions addressed.

- The CGE complements the SD model by modelling the economic impacts of a given policy and by providing this information as an input to the SD model for further modelling of environmental and social impacts.

- In conjunction to the CGE model, green extensions of the IO model and SAM can be used to provide information on green sectors to the CGE model.

# DIAGRAM OF THE IGEM FRAMEWORK SHOWING THE LINKAGES BETWEEN THE SD, CGE AND IO-SAM MODELS



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# THE IGEM FRAMEWORK

- The two main added values of the IGEM framework project are:

- to develop some general guidelines on how to “green” the IO-SAM, the CGE and the SD models;

- to develop a methodology on how to link these greened models.

# GREENING THE MODELS – IO-SAM

- A green IO-SAM model is featured by making the green sectors explicitly distinguished from their like sectors which are run based on conventional technologies and practices.

- Disaggregation or creation of new green sectors may require specific data and IO techniques, depending on the request for resolution at the sector, process or technology levels.

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# GREENING THE MODELS – IO-SAM

- The process of sector disaggregation includes two steps:

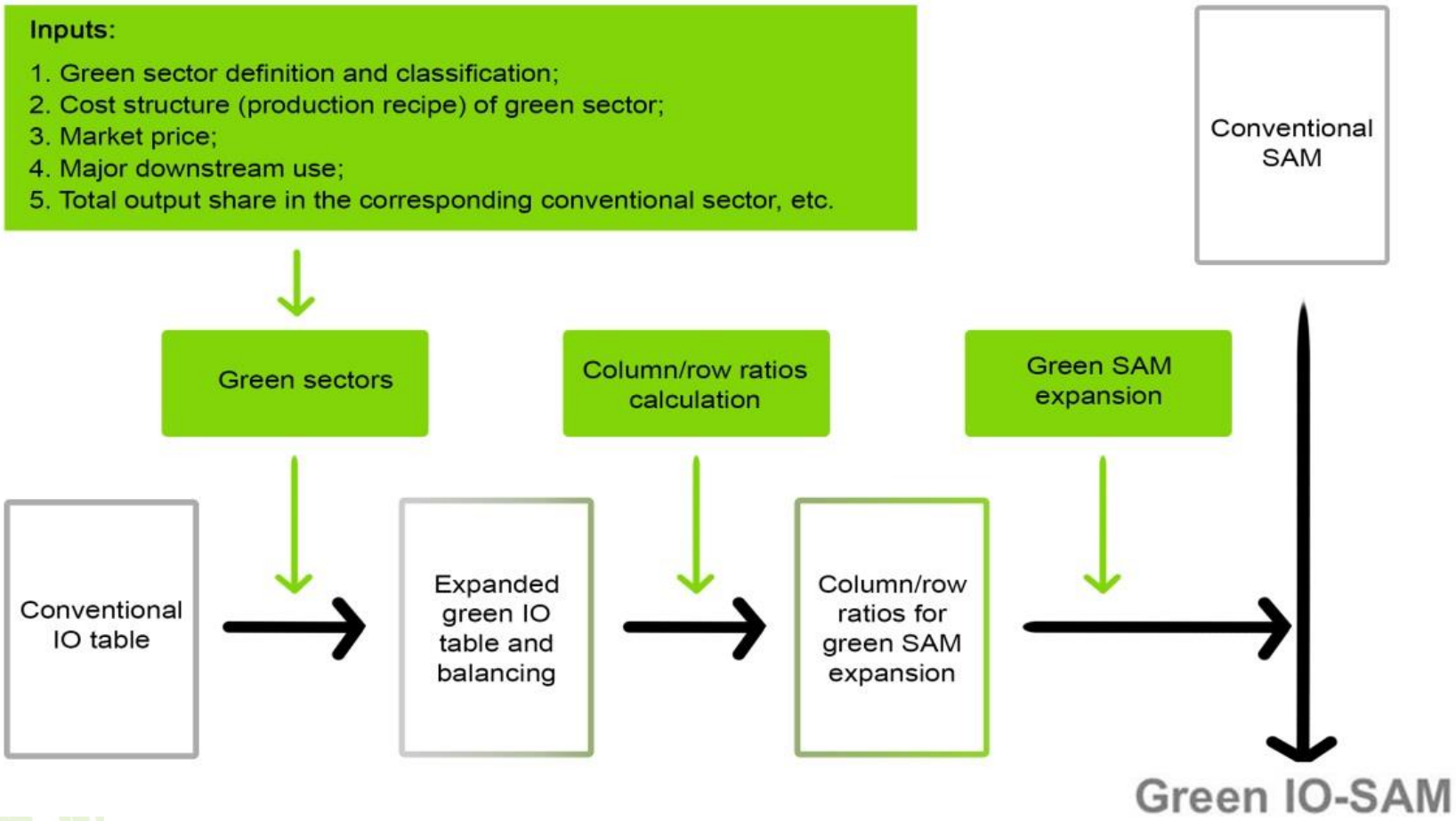
- a conventional IO model with aggregation of green and non-green sectors will be disaggregated to present detailed green sectors;

- a green SAM will be constructed based on the built-up green IO model.

# STEP 1: CREATE AN EXPANDED (OR GREEN) IO

| | | Purchasing sectors | | | | | | Final demand | | | | Total outputs ($X$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $1$ | … | $j$ | … | $n$ | $n+1$ | | | | | |
| Producing sectors | $1$ | $x_{11}$ | … | $x_{1j}$ | … | $x'_{1n}$ | $x'_{1,n+1}$ | $c_1$ | $i_1$ | $g_1$ | $e_1$ | $X_1$ |
| | ⋮ | ⋮ | | ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| | $i$ | $x_{i1}$ | … | $x_{ij}$ | … | $x'_{in}$ | $x'_{i,n+1}$ | $c_i$ | $i_i$ | $g_i$ | $e_i$ | $X_i$ |
| | ⋮ | ⋮ | | ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| | $n$ | $x'_{n,1}$ | … | $x'_{n,j}$ | … | $x'_{n,n}$ | $x'_{n,n+1}$ | $c'_n$ | $i'_n$ | $g'_n$ | $e'_n$ | $X'_n$ |
| | $n+1$ | $x'_{n+1,1}$ | … | $x'_{n+1,j}$ | … | $x'_{n+1,n}$ | $x'_{n+1,n+1}$ | $c'_{n+1}$ | $i'_{n+1}$ | $g'_{n+1}$ | $e'_{n+1}$ | $X'_{n+1}$ |
| Value-added ($v'$) | | $v_1$ | … | $v_j$ | … | $v'_n$ | $v'_{n+1}$ | $v_c$ | $v_i$ | $v_g$ | $v_e$ | $V$ |
| Imports ($m$) | | $m_1$ | … | $m_j$ | … | $m'_n$ | $m'_{n+1}$ | $m_c$ | $m_i$ | $m_g$ | | $M$ |
| Total inputs ($X$) | | $X_1$ | … | $X_i$ | … | $X'_n$ | $X'_{n+1}$ | $C$ | $I$ | $G$ | $E$ | |

# STEP 2: CREATE AN EXPANDED (OR GREEN) SAM



# GREENING THE MODELS – IO-SAM

## Spatial extensions of the IO-SAM

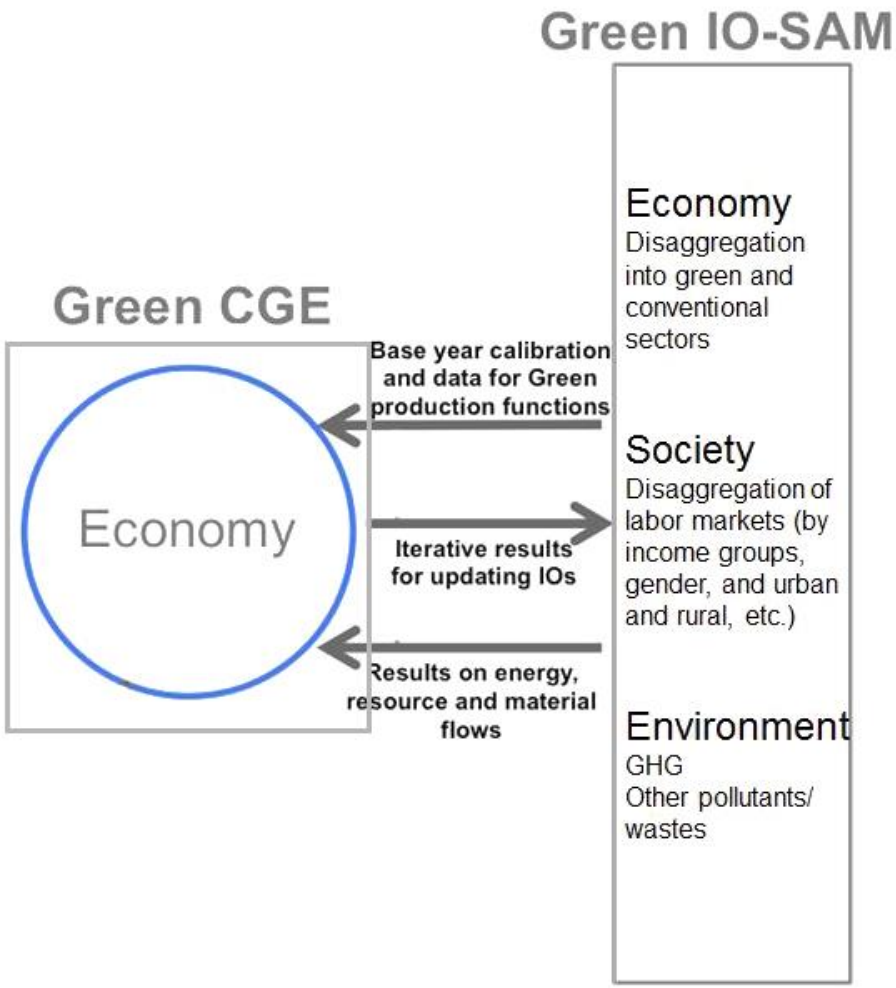
- A national or regional economy within a country is often an open system which interacts with other countries or regions through imports/exports or inflows/outflows of energy, materials, natural resources, capital resources and human resources.

- To capture the spatial impacts associated with trade, a MRIO model can fulfil well in terms of presenting the locations of the origin and destination of individual trade flows related to the inter-sectoral transactions.

# GREENING THE MODELS – CGE

- A standard CGE may be transformed into a “green” CGE either by using input data on green sectors coming from the expanded IO-SAM; or by making specific modifications to the conventional CGE model to reflect the use of environmentally efficient technologies. These two approaches can be integrated.

# GREEN CGE AND GREEN IO-SAM



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## GREENING THE MODELS – CGE

- The CGE would be modified in 3 ways to be greened:
- The first modification implies incorporating the latest data available in the SAM used in the simulations.
- The second modification deals with its treatment of water.
- Third, the sectors in the model will be re-aggregated from the new input-output tables and a special “green” production sector will be constructed.

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# GREENING THE MODELS – SD

- The System Dynamics model component of the IGEM framework is designed to focus on green policy analysis and to work in concert with the green CGE and green IO-SAM models.

- To do so, a green version SD model was developed with the sector structure necessary to address the green economy policies under consideration, while keeping the model tractable for interlinking with the CGE and IO components of the IGEM framework.

# LINKING THE MODELS – THE IO-SAM WITH THE CGE

- The IO-SAM is the database of an empirical CGE model. An IO table is usually used to build the production function for the intermediate inputs and value-added composite at the top level of the nesting approach.

- The base-year SAM is usually used for the calibration of a CGE model.

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# LINKING THE MODELS – THE CGE WITH THE SD

- To ensure consistency between the CGE and the SD models, the following conditions need to be fulfilled:

- Parameter selection;
- Variable trends;
- Other common variables;
- Model calibration;
- Initial conditions.

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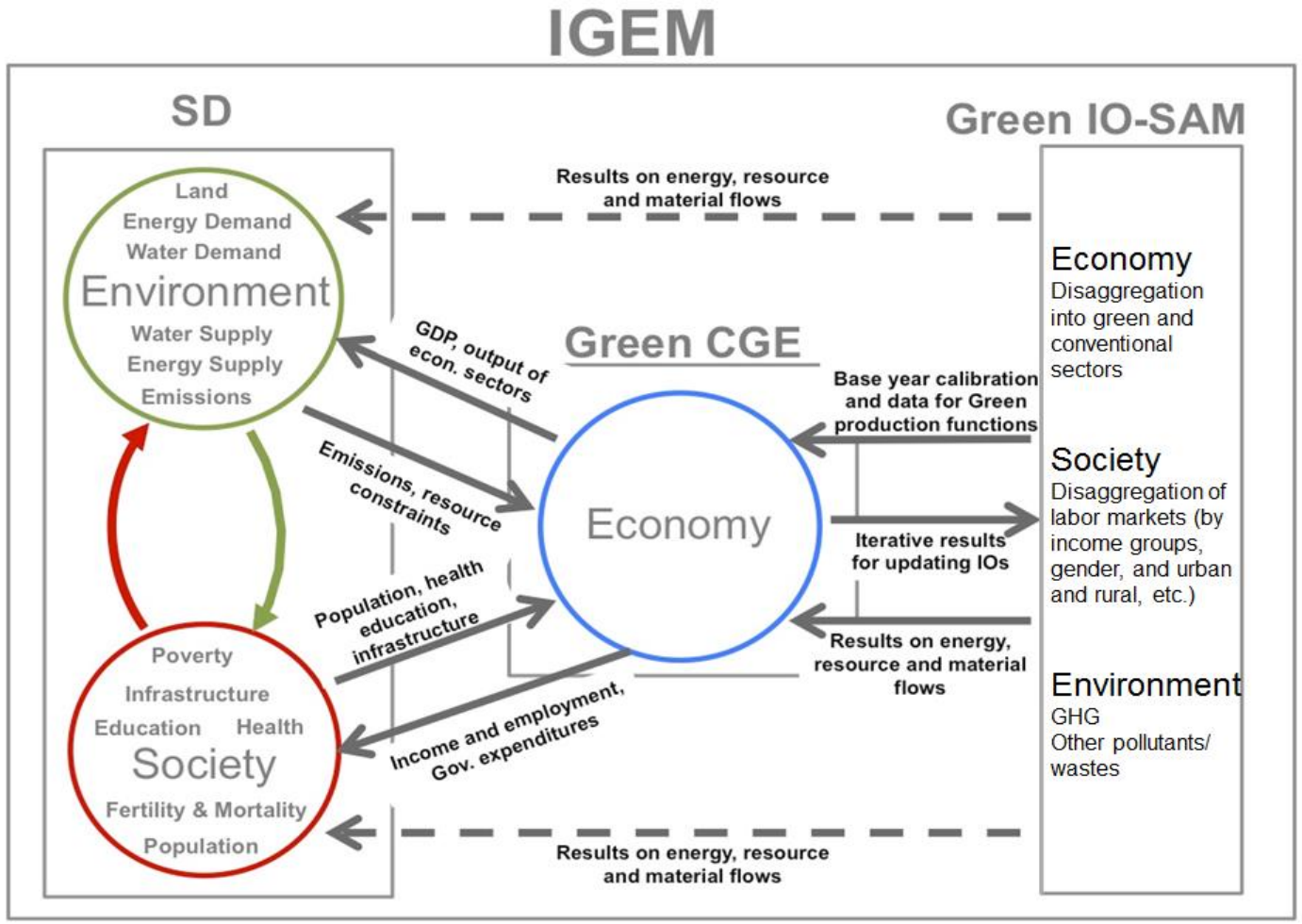
# LINKING THE MODELS – THE CGE WITH THE SD

- The IGEM framework integrates two types of linkages between the CGE and the SD model:

- A **soft** linkage - the entire scenario is run on one model, the results are fed into the other model, and vice versa.

- An **hard** linkage - the CGE and SD models are manually coupled. Each model is run for two-year iterations. After each iteration, designated output values from each model are transferred as inputs to the other model.

# DIAGRAM OF IGEM FRAMEWORK INFORMATION STRUCTURE



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# LINKING THE MODELS – THE IO-SAM WITH THE SD

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

- following a **target-driven** approach;

- following an **investment-driven** approach.

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# 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 CO2)

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 CO2 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)

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# INVESTMENT (OR PRICE)-DRIVEN APPROACH

**Green CGE**

1) Calibrate the model to include the tax rate of Y USD/tonne on $CO_2$ emissions

2) Calculate economic impacts following the implementation of the carbon tax (redistribution of tax revenues, production, trade, employment effects, etc.)

5) Use SD simulation results to estimate productivity impacts in the CGE

(1) →

← (2)

**Green System Dynamics**

3) Insert variables predicted by the CGE in SD to evaluate impact on SD sectors following the implementation of the carbon tax (redistribution of tax revenues, impact on physical units)

4) In particular, calculate how many $CO_2$ emissions will be reduced and what are the health impacts

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# THE APPLICATION OF THE IGEM FRAMEWORK

- Mexico is the world's 13th largest emitter of CO2 emissions and is projected to be the world's 5th largest economy in 2050.

- Mexico introduced a carbon tax on fossil fuel production in 2014 in order to create awareness of CO2 emissions, and to put a price to carbon and to promote the use of cleaner fuels.

  - The carbon tax applies only to the use of fossil fuels.
  - The approximate price of carbon was set at 3.5 USD/tCO2eq.

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# CARBON TAX SCENARIOS TESTED BY THE IGEM FRAMEWORK

| Scenarioc | Tax rate | CGE | System Dynamics |
|---|---|---|---|
| **Scenario 1 -** Feebate scenario with low tax rate (FBL) | 3.5 USD/tCO2eq | 1) Estimate the economic effects of feebate scenarios compared to a revenue neutral carbon tax and a business-as-usual scenario<br><br>3) Use results from the SD to estimate effects of increased longevity on productivity | 2) Estimate the social and environmental impacts resulting from the CGE simulation (health and emissions) |
| **Scenario 2 -** Feebate scenario with high tax rate (FBH) | 25 USD/tCO2eq | | |
| **The two feebate scenarios will be compared to:** | | | |
| **Rebate scenario** (lump sum) with high (RH) and low (RL) tax rates | 3.5 and 25 USD/tCO2eq | | |
| **Business-as-usual scenario** (BAU) | No carbon tax | | |

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# RESULTS FROM THE CGE – SCENARIO 1

## Aggregate and sectoral effects of a revenue-neutral carbon tax, in 2036

| | Column 1 | Column 2 |
|---|---|---|
| **Aggregate results** | FBL vs. BAU | FBL vs. RL |
| GDP | -0.1670% | 0.2652% |
| Investment | 0.4514% | 1.0984% |
| Government | -0.2072% | -0.0125% |
| Capital Stock | -0.3253% | 0.0078% |
| **Welfare** | | |
| Agent 1 (20% poorest) | -0.1174% | -0.0364% |
| Agent 2 (3-5 deciles) | -0.1119% | 0.0097% |
| Agent 3 (6-8 deciles) | -0.1192% | 0.0167% |
| Agent 4 (20% richest) | -0.1407% | 0.0321% |
| Aggregate welfare agents 1-4 | -0.1279% | 0.0078% |
| Government welfare | 0.0000% | 0.0000% |
| **Selected sectors** | | |
| Agriculture | -0.7599% | -0.3504% |
| Manufacturing | -1.0087% | -0.3915% |
| Oil | -5.1713% | -1.5797% |
| Natural gas | -4.7644% | -1.3594% |
| Mining | -6.2312% | 0.2144% |
| Refining | -4.1215% | -1.1295% |
| Electricity | 5.6699% | 6.2579% |

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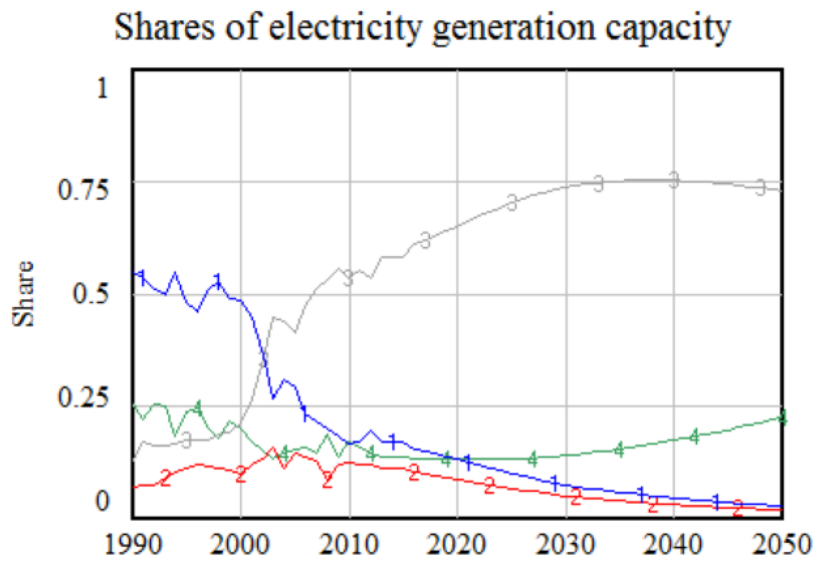
# RESULTS FROM THE CGE – SCENARIO 2

## Aggregate and sectoral effects of a revenue-neutral carbon tax, in 2036

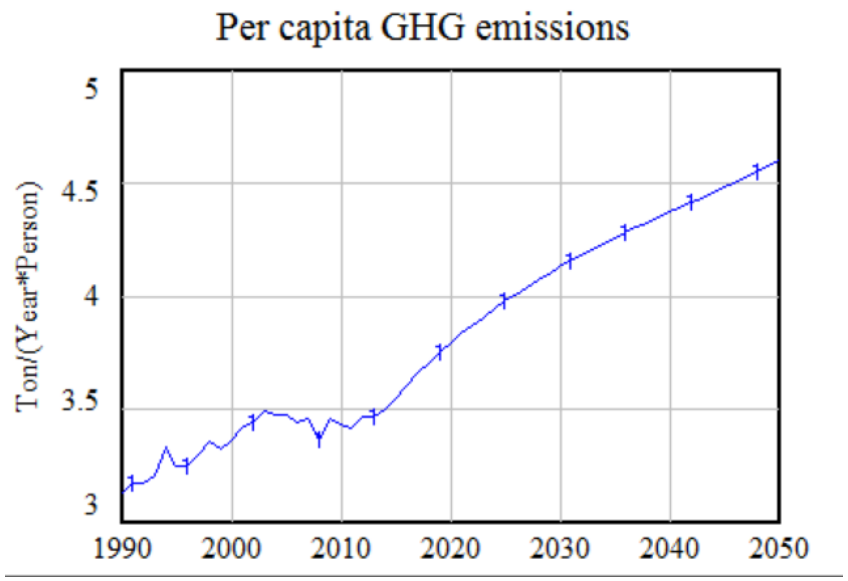
| | Column 1 | Column 2 |
|---|---|---|
| **Aggregate results** | FBH vs. BAU | FBH vs. RH |
| GDP | -1.9318% | 1.0186% |
| Investment | -0.2010% | 3.4304% |
| Government | -1.4058% | 0.1768% |
| Capital Stock | -1.3240% | 1.0674% |
| Welfare | | |
| Agent 1 (20% poorest) | -0.8717% | -0.2434% |
| Agent 2 (3-5 deciles) | -0.8511% | 0.0231% |
| Agent 3 (6-8 deciles) | -0.8936% | 0.0792% |
| Agent 4 (20% richest) | -1.0541% | 0.1780% |
| Aggregate welfare agents 1-4 | -0.9601% | 0.0951% |
| Government welfare | 0.0000% | 0.0000% |
| **Selected sectors** | | |
| Agriculture | -5.1320% | -2.1984% |
| Manufacturing | -7.4112% | -2.9469% |
| Oil | -28.5069% | -3.1453% |
| Natural gas | -28.6476% | -4.0895% |
| Mining | -94.1274% | -0.1850% |
| Refining | -25.2683% | -3.7044% |
| Electricity | 13.3272% | 23.1085% |

# RESULTS FROM THE SD – BAU SIMULATION

A. BAU




B. BAU




*Oil: Blue (1)*

*Coal: Red (2)*

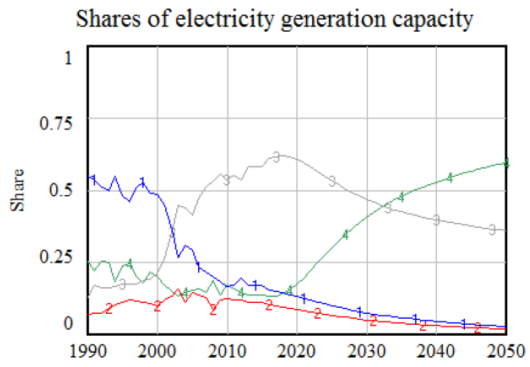
*Gas: Gray (3)*

*Renewables: Green (4)*

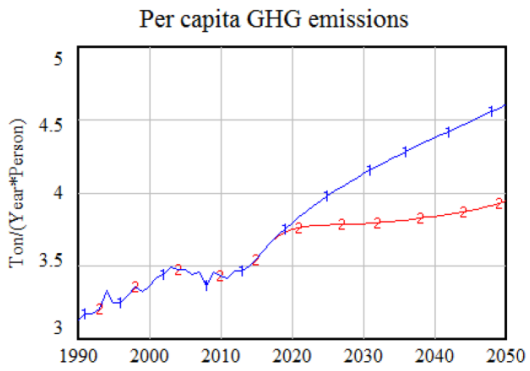
*BAU: Blue (1)*

# RESULTS FROM THE SD – FEEBATE SCENARIO

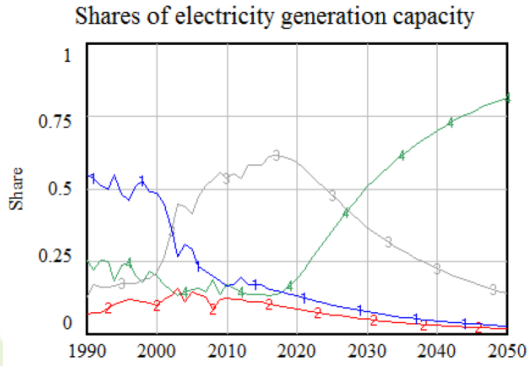
A. USD 3.5 feebate (FBL)



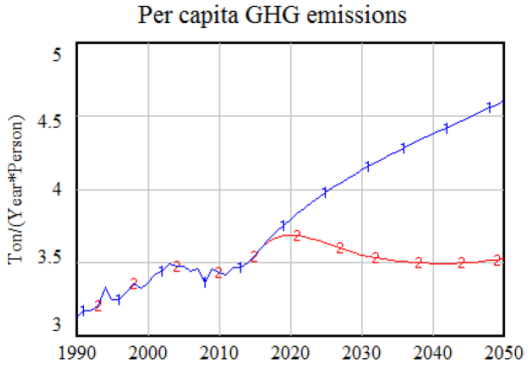

B. USD 3.5 feebate (FBL)




C. USD 25 feebate (FBH)




D. USD 25 feebate (FBH)

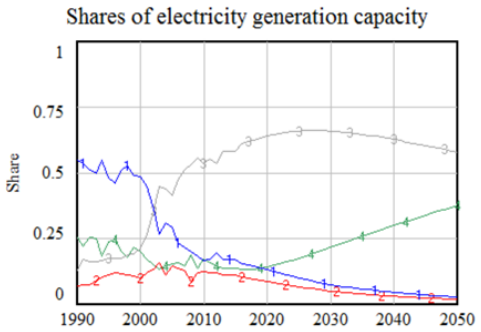



*Oil: Blue (1)*
*Coal: Red (2)*
*Gas: Gray (3)*
*Renewables: Green (4)*

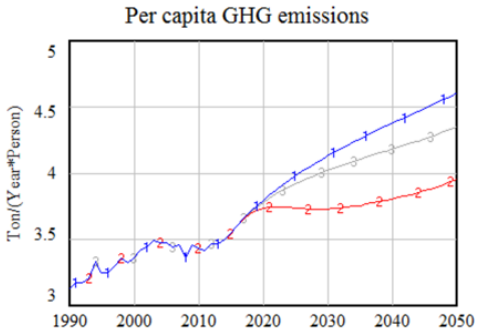
*BAU: Blue (1)*
*With feebate: Red (2)*

# RESULTS FROM THE SD – REBATE SCENARIO

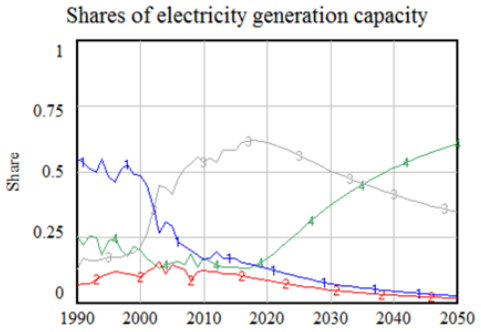
A. USD 3.5 Carbon tax with lump sum rebate (RL)



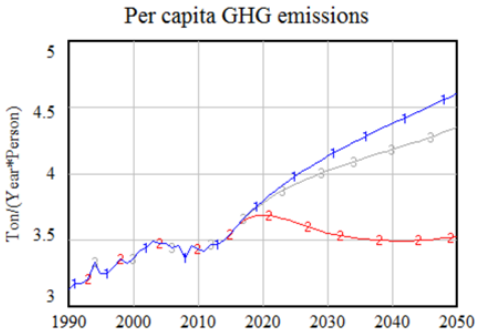

B. USD 3.5 feebate (FBL) compared with USD 3.5 Carbon tax with lump sum rebate (RL)




C. USD 25 Carbon tax with lump sum rebate (RH)




D. USD 25 feebate (FBH) compared with USD 25 Carbon tax with lump sum rebate (RH)

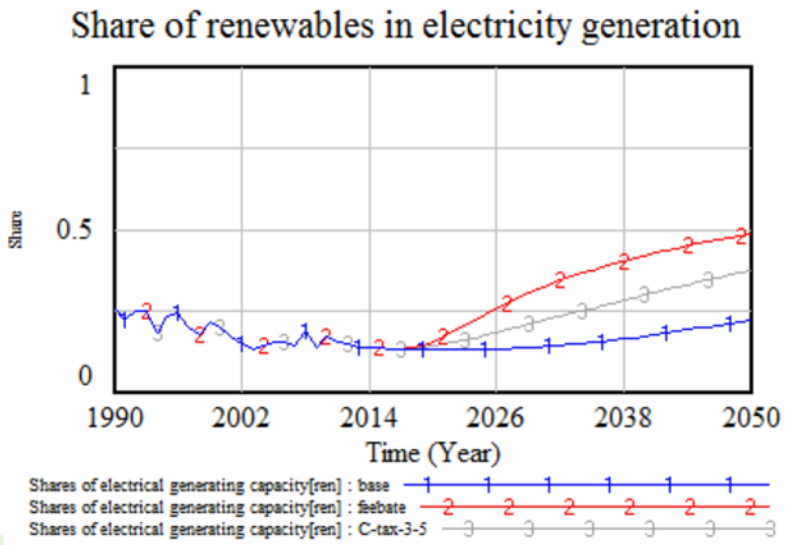



*Oil: Blue (1)*
*Coal: Red (2)*
*Gas: Gray (3)*
*Renewables: Green (4)*

*BAU: Blue (1)*
*With feebate: Red (2)*
*With carbon tax and lump sum rebate: Gray (3)*

# EVOLUTION OF THE SHARE OF RENEWABLE ENERGY CAPACITY FOLLOWING BAU, FBL, RL, FBH AND RH SCENARIOS

A. With low tax rate of USD 3.5

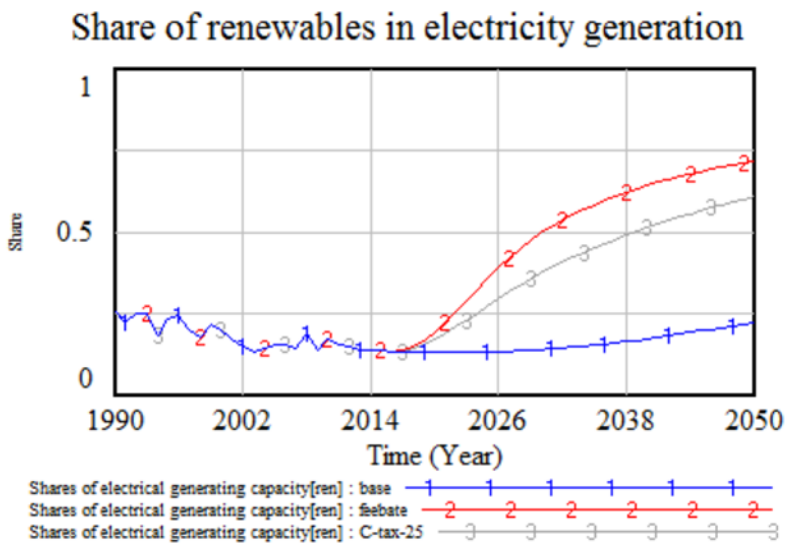



Blue: BAU

Red: FBL

Gray: RL

B. With high tax rate of USD 25




Blue: BAU

Red: FBH

Gray: RH

## RESULTS FROM THE IGEM

- The IGEM simulation consisted in running the dynamic CGE model in conjunction with the SD model, and using output gathered from the SD model to supplement and adjust the CGE input parameters.

- Since the burning of fossil fuels generates particulates and other harmful waste, a carbon tax would have positive impacts on the health of the population, which in turn should increase productivity as healthier individuals typically work more and produce more.

- Based on these assumptions, the IGEM was applied considering **any increase in longevity equal to an increase in productivity.**

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# RESULTS FROM THE IGEM

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

| | RH with longevity vs BAU | RH with longevity vs RH no longevity | FBH with longevity vs. FBH no longevity |
|---|---|---|---|
| GDP | -2.5608% | 0.3332% | 1.2949% |
| Investment | -2.7583% | 0.7796% | 3.8981% |
| Government | -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) | -0.9121% | 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% |

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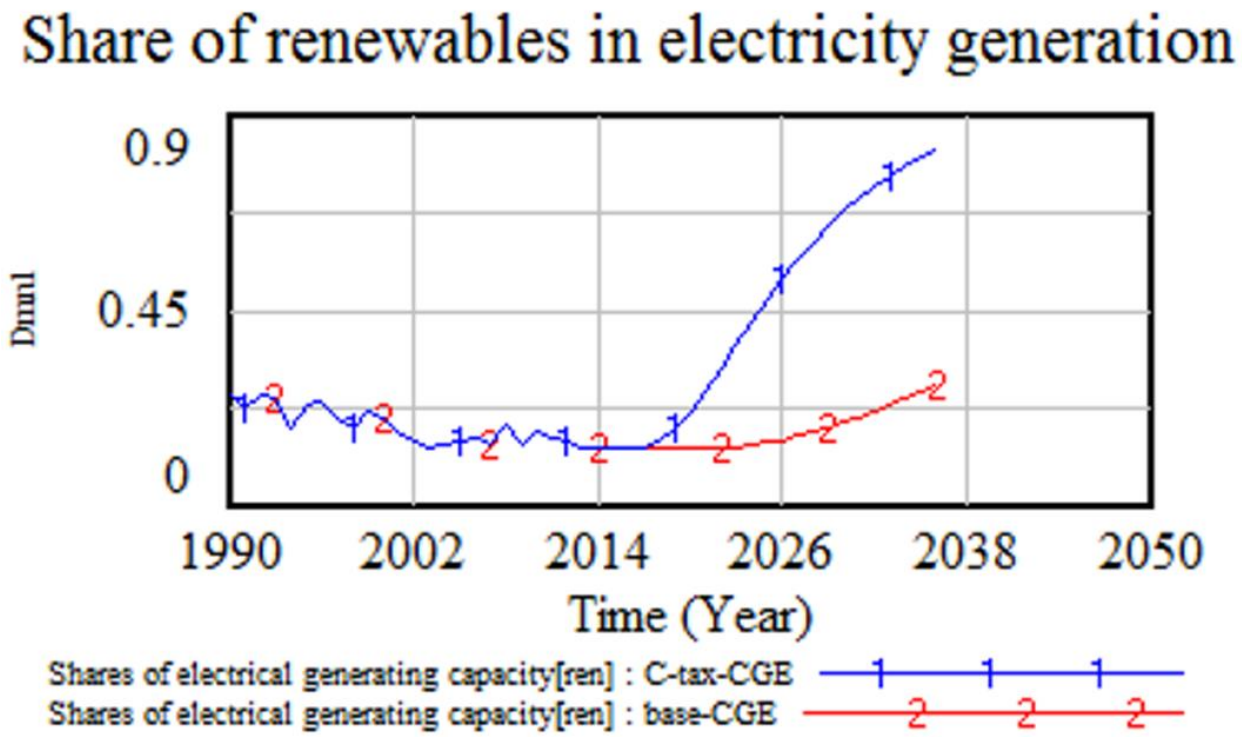
## RESULTS FROM THE IGEM



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# SUMMARY OF RESULTS FROM THE IGEM

| Main results from CGE simulation | Main results from SD simulation | Main results from IGEM simulation (SD-CGE) |
|---|---|---|
| Scenario 1: FBL-BAU<br>• 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.<br><br>Scenario 2: FBH-RH<br>• Feebate scenario will result in higher values for aggregate indicators (e.g. GDP, Investment, etc.) up to 2036 than rebate scenario.<br><br>Both scenarios<br>• 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<br>• Low tax levels are of limited capacity in inducing a transformation of the electricity generation mix.<br><br>Scenario 2: FBH-BAU/RH<br>• Feebate policy, with the high carbon tax on full emissions, achieves the greatest carbon emission reduction. | • GDP grows up to 1.3% (0.33%) when the effect of lower emissions on longevity and later on labour productivity is taken into account in the feebate (rebate) scenario.<br><br>• The gains are evenly distributed over all consumers, with a slight bias towards the richest agents in the economy.<br><br>• Government revenues also increase. |

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## CONCLUSIONS

- on **greening**: the IGEM framework shows how the CGE can be greened through the inclusion of additional sectors and/or by using a green IO-SAM as input, and how the SD model can be greened, by disaggregating a particular sector to address environmental and social questions of interest to policymakers.
- on **coupling**: the IGEM framework presents a methodology on how to link 3 modelling tools (IO-SAM, CGE, SD) by identifying the main entry points between the models and how this linkage can be reinforced following different rounds of integration.
- In Mexico, GDP growth is enhance when the effect of lower emissions on longevity and later on labor productivity is taken into account. Linkages goes in both directions (CGE ⟷ SD)

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# APPLICATION OF T21 FRAMEWORK FOR GREEN ECONOMY POLICY ANALYSIS IN PERU

Daniel De La Torre Ugarte, PhD

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## OBJECTIVE OF THE STUDY

- To perform an ex-ante quantitative assessment of policies to green the Peruvian economy.
- The policies evaluated seek to support Peru's effort to reach the national objective of sustainable development, improve competitiveness, economic diversification, and employment generation.

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# PROPOSITO DEL ESTUDIO CUANTITATIVO

Steps:

- Nationalize the T21 Framework: T21 -Peru
- Expand T21-Peru to analyze green policies

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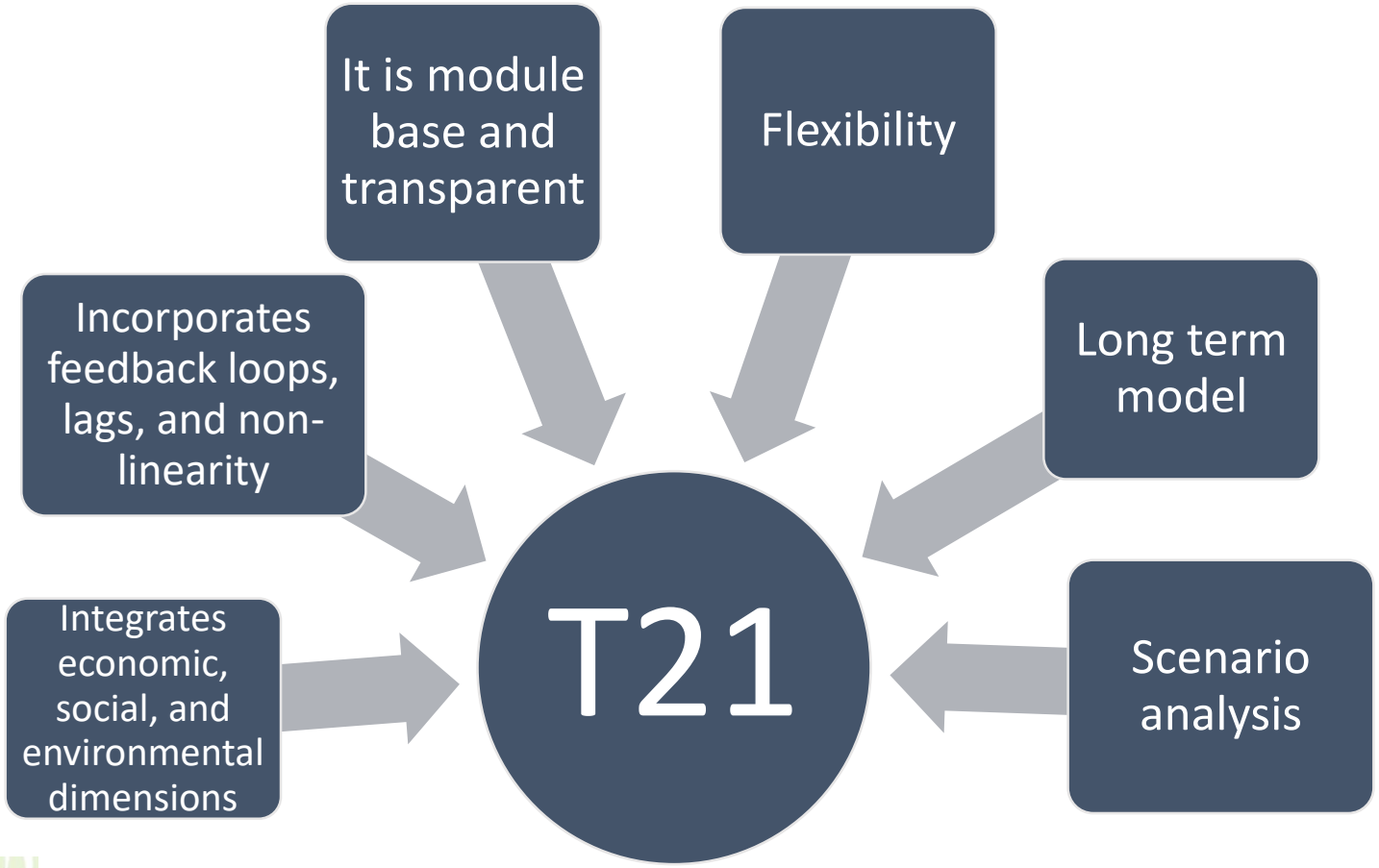
# WHY THE T21 MODEL



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# MODULES OF THE T21 AND T21-PERU MODELS

| Social | Economic | Environmental | Green |
|---|---|---|---|
| 1. Population<br>2. Fertility<br>3. Mortality<br>4. Education<br>5. Health<br>6. Employment<br>7. Income distribution | 8. Infrastructure<br>9. Agriculture<br>10. Industry<br>11. Mining<br>12. Services<br>13. Aggregate Production and Investments<br>14. Households<br>15. Government<br>16. Gov. Financing<br>17. Balance of Payments | 17. Land<br>18. Water demand<br>19. Water supply<br>20. Energy demand<br>21. Energy supply<br>22. Fossil Fuel and GHG emissions | Agrículture<br>Forestry<br>Transportation |

# T21-PERU MODEL: MINING AND TRADE BALANCE

## MINING

| | Base | | Perú |
|---|---|---|---|
| Development | No mining module | → | Matrix of investment and production of mining projects through 2035 |

## Balanza Comercial

| | Base | | Perú |
|---|---|---|---|
| Assumptions | TB estimated as a residual | → | Link X to sector production |

# T21-PERU MODEL: FISCAL ADJUSTMENT RULE

| | Base | | Perú |
|---|---|---|---|
| Development | Public debt a function of financing needs of the modules | → | Integrate MEF fiscal rule |

# T21-PERU MODEL: AGRICULTURE

| | Base | | Perú |
|---|---|---|---|
| Disaggregation | Cereals and other crops | → | Geographic regions |
| Supuestos | Production in TONs | → | Regional production in value |
| Supuestos | Potential Yields | → | No potential yield |

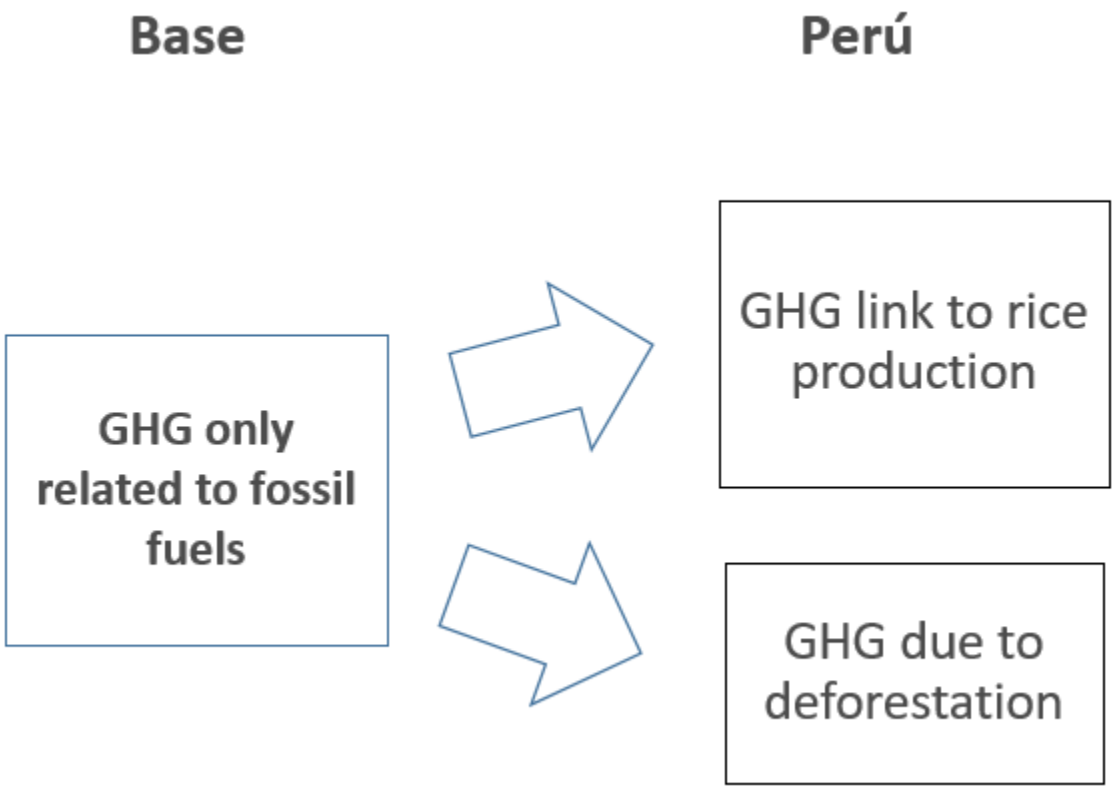
Parameters

| Region | L | K | T |
|---|---|---|---|
| Coast | 0.05 | 0.3 | 0.65 |
| Highland | 0.05 | 0.01 | 0.94 |
| Amazon | 0.05 | 0.05 | 0.9 |

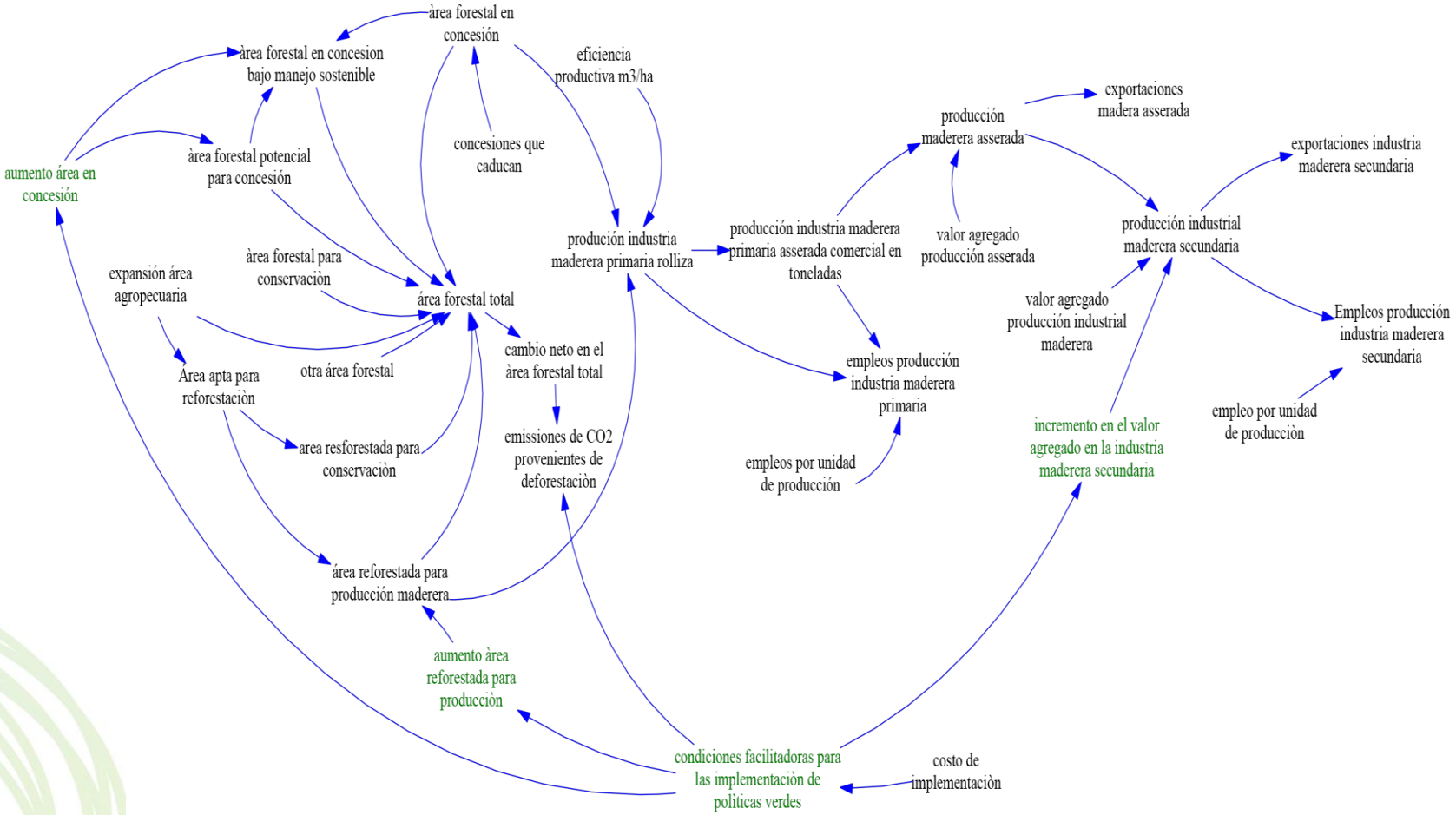
# T21-PERU MODEL: WATER DEMAND AND SUPPLY

| | Base | | Perú |
|---|---|---|---|
| Water Demand | Lack of data population consumption | → | Data from Lima as national proxy |
| New variables | Average Rainfall | → | Rainfall costa + highland Amazon: outflow |
| | | | River flow of rivers that supply Lima |

# T21-PERU MODEL: GHG EMISSIONS



# FORESTRY MODULE: CAUSALITY LINKS



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## LESSONS LEARNED

- T21 modular  structure is an advantage in the nationalization of the model. This also is important for the continuous development and use of the model.
- Data and relationships of T21 framework provides a good starting point in all modules where local information is not available.
- Calibration process remains a black box. It makes difficult the process of nationalization.
- It will more efficient to define new sectors or policies before the formal training sessions on the use of the T21 Framework.

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# GENERAL COMMENTS

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## COMMENTS: GENERAL

- Sustainable development challenges differ by location, so good that this initiative is avoiding “one size fits all”
- T21 appears to be a useful model for policy analysis for the green economy and sustainable development
  - It includes relevant dynamics
  - It is flexible and possible to extend
- The examples shown here are evidence of a “learning community” with experiences to share – a good sign
- How does GGKP/PAGE view the role of models in policy development?
- In particular: is there an effort to secure meaningful and broad stakeholder input in model design and interpretation?

# MODELS IN POLICY

- Model evaluation and validation is tricky in a policy setting: calibrate against historical data, but apply in counterfactual futures – how to evaluate its performance?
- Structure represents an interpretation of the system, which might be contested
- Models exclude as well as include: There is a bias towards modeling what can be modeled, excluding “soft” factors, like expectations, trust, and perceptions of fairness
- But those soft dynamics often dominate daily life, can strongly influence the acceptability of policies, and are particularly relevant in a transition (e.g., from conventional to green)

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## COMMENTS & QUESTIONS: PERU

- A nice example of “leveraging” an existing model and making it appropriate in a country context
- Note the need for a modular and adaptable long-run model
- How did you estimate exports? How vulnerable is BoP to fluctuations in global price/demand of mining & timber products?
- Cobb-Douglas for crops makes me nervous: biophysical constraints are real and near. Which crops do not have potential yield estimates?
- Forest: “productive efficiency”: How does it compare to increment? Links more to standing stock than to land area
- Why only implementation cost affecting conditions for green implementation? And how does that feed into CO2 emissions?

# COMMENTS & QUESTIONS: IGEM

- A sensible combination of these models, with interesting and policy-relevant results for Mexico; like T21, this extension can be applied elsewhere
- Strategy of combining models is a good one: focus on communication and leverage expertise
- How sensitive are the results to the specification of the green cost structures? I-O matrices are dense, so might understate or overstate impact
- To what extent are green outputs substitutable? How deeply does “green” penetrate? E.g.
  - intermittent renewables might need a new grid/smart devices
  - bio-based chemical industry might have different platform chemicals (carbohydrates rather than hydrocarbons)
- Methodological question:
  - SD emphasizes out-of-equilibrium processes
  - CGE computes equilibrium states
  - How do you reconcile these two?

# *Audience Q&A*

# *Closing Remarks*

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*Thank you for attending this webinar on*

***The Integrated Green Economy Modelling (IGEM) framework***

- This webinar was **recorded** and will be **uploaded** to the GGKP website: www.ggkp.org
- If you have any further questions about the webinar please email: contact@ggkp.org
- The GGKP asks you to complete a **survey** which will be sent out after this webinar.