THE INTEGRATED GREEN ECONOMY MODELLING FRAMEWORK
An Overview
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The Integrated Green Economy Modelling Framework

An Overview
WHAT IS AN INCLUSIVE GREEN ECONOMY?

An Inclusive Green Economy is one where growth is driven by investments that 1) reduce carbon emissions and pollution, 2) enhance energy and resource efficiency, 3) prevent the loss of biodiversity and ecosystem services, 4) increase the number of decent jobs, and 5) ensure equitable distribution of income and wealth. It is a vehicle for delivering the Sustainable Development Goals, responding to three sets of challenges facing humanity today: persistent poverty, inequitable sharing of prosperity, and overstepped planetary boundaries.

WHAT IS A MODEL?

A model is a simplified representation of complex relationships in reality. For example, there are many factors driving climate change, but a model can relate global warming mainly to the burning of fossil fuels, thereby helping to focus policy interventions.

A model can be theoretical or empirical. In the above example, the theory states that as people use more fossil fuels, the world will get warmer. We can test this by observing whether the world is actually getting warmer due to increased burning of fossil fuels.

WHAT IS THE INTEGRATED GREEN ECONOMY MODELLING FRAMEWORK?

Different models exist to answer different questions. A model named “Input/Output-Social Accounting Matrix” (IO-SAM), for example, is often used to answer questions such as how renewable energy contributes to the overall economy including employment and how it interacts with other industries. Another model named “Computable General Equilibrium” (CGE) is typically used to answer questions like how a fossil fuel subsidy reform is likely to impact productivity in the renewable energy sector and what the implications of such a reform are on production, employment, trade, government revenue, and income distribution.

A further example is a System Dynamics (SD) model, which is good at tracking a policy change’s system-wide economic, social and environmental effects.

A transition to an Inclusive Green Economy requires a combination of policy interventions with crosscutting impacts. A single model, therefore, is often inadequate to answer all the essential questions. For example, an SD model may help us track the impacts of renewable energy investments on total economic output, carbon emissions and access to clean energy, but it is not so good at showing the short-term impacts on jobs across sectors. In this case, the use of IO-SAM in combination with a CGE model can make up for that deficiency.

This is the logic for our effort to integrate three major modelling tools: IO-SAM, CGE, and SD. The purpose is to help answer a wide range of questions that we often come across in the making of green economy policies. In what follows, we will describe each individual model and their integration with an example from Mexico.
A GREEN IO-SAM MODEL

An IO model is a table that tracks the relationship between the total input into production (such as labour, raw materials, energy, information, etc.) and the corresponding total output of goods and services. Table 1 illustrates an IO table with agriculture and industry sectors, which can be disaggregated (or “greened”) by their respective green components (see Table 2), distinguished from other components that use conventional technologies and practices. The “final demand” in the tables refer to things produced for final consumption.

In addition, a SAM, which is embedded in the IO table, presents the structure of a country’s overall economy, providing information on buyers in columns and producers in rows (see Table 3). Columns and rows can also be disaggregated by “factors of production” (i.e. land, labour and capital), households, companies, and governments (the latter two are omitted in Table 3 for simplicity). A SAM’s main objective is to identify who pays and who receives money.

Almost all the data in a SAM can be obtained directly or derived from the corresponding IO table. In Table 3, the grey cells can be directly obtained from Table 2. The column sum and row sum entries in white are calculated by summing across row entries or across column entries for each relevant agent. The entries shaded in orange can be calculated directly by using the row-sum and column-sum equality rule for each agent. For example, “Factor income” equals “Factor expenditure”, based on which “Factor income to households” can be calculated.

A GREEN CGE MODEL

A CGE model simulates how an economy might react to changes in policy (e.g. a tax or subsidy), technology (e.g. renewable energy) or other external factors (e.g. changes in tariff rates). The model provides information on the levels of supply and demand as well as the price that is supposed to bridge any gap between the two across various markets. The model analyses how a policy’s impact transmits through multiple markets.

We construct a green CGE model by incorporating the latest data available in the green SAM (i.e. a SAM with disaggregated green sectors). We then disaggregate the data from the new IO tables and subsequently construct a special “green” production sector. For example, there is a different treatment of the water sector since water is not only a consumer good but also a major input to the agricultural and manufacturing sectors. To account for this added role of water in the model, the “green” IO-SAM mentioned above is used to treat water as a primary input in the green CGE model. A similar disaggregation is done for those manufacturing, refining, and chemical subsectors where environmentally efficient technologies (such as wind turbines, solar panels, efficient lights, etc.) are expected to occur.

Figure 1 is an illustration of a CGE model. On the right-hand side, there are different consumption goods, for example: food, household goods, consumption services, energy, private and public transport, gasoline, housing and water. These are produced by combining the outputs of the producing sectors through a green IO matrix (as discussed in the previous
### TABLE 1: AN ILLUSTRATIVE IO TABLE (MONETARY UNIT)

<table>
<thead>
<tr>
<th>Purchasing Sectors</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Producing Sectors</strong></td>
<td>Agriculture</td>
<td>Industry</td>
<td>Final Demand</td>
<td>Total Output (Revenue)</td>
</tr>
<tr>
<td>Agriculture</td>
<td>160</td>
<td>90</td>
<td>50</td>
<td>300</td>
</tr>
<tr>
<td>Industry</td>
<td>90</td>
<td>210</td>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>Value Added</td>
<td>50</td>
<td>100</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Total Input (Cost)</td>
<td>300</td>
<td>400</td>
<td>150</td>
<td>850</td>
</tr>
</tbody>
</table>

### TABLE 2: AN ILLUSTRATIVE GREEN IO TABLE (MONETARY UNIT)

<table>
<thead>
<tr>
<th>Purchasing Sectors</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Producing Sectors</strong></td>
<td>Conventional Agriculture</td>
<td>Green Agriculture</td>
<td>Conventional Industry</td>
<td>Green Industry</td>
</tr>
<tr>
<td>Conventional Agriculture</td>
<td>90</td>
<td>10</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Green Agriculture</td>
<td>20</td>
<td>40</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Conventional Industry</td>
<td>50</td>
<td>10</td>
<td>130</td>
<td>30</td>
</tr>
<tr>
<td>Green Industry</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Value Added</td>
<td>30</td>
<td>20</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Total Input (Cost)</td>
<td>200</td>
<td>100</td>
<td>300</td>
<td>100</td>
</tr>
</tbody>
</table>

### TABLE 3: AN ILLUSTRATIVE GREEN SAM (MONETARY UNIT)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Factor</th>
<th>Final Demand</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Industry</td>
<td>Green Agriculture</td>
<td>Capital</td>
<td>Labour</td>
</tr>
<tr>
<td>Intermediate inputs</td>
<td>Value added from capital services</td>
<td>Factor income to households</td>
<td>Household income</td>
</tr>
<tr>
<td>Capital</td>
<td>Labour</td>
<td>Final Demand</td>
<td>Total</td>
</tr>
<tr>
<td>Activity cost (gross input)</td>
<td>Factor expenditures</td>
<td>Household expenditure</td>
<td></td>
</tr>
</tbody>
</table>
section). On the left-hand side, consumers supply factors of production (such as labour and capital) to firms while demanding goods and services from them, whereas firms in the middle of the diagram demand factors of production and supply goods and services, all through market mechanisms. Consumers are divided into four groups from 1 to 4 where the lowest income agents are represented in group 1 (20% poorest) and highest income agents in 4 (20% richest).

Production allows for different degrees of substitution between labour (formal and informal), capital, energy, and non-energy inputs. Technical progress is external to the model (i.e. not determined by the interactions of the factors within the model). The government collects revenues derived from all taxes and tariffs and spends its revenues on goods and services generated from the various private production sectors through markets.

A GREEN SD MODEL

An SD model allows us to explore the interconnections among various components of a socioeconomic system. Each of the components (e.g., population, industry, and environment) connects others by:

- **Flows**: a flow can be thought of as a faucet and pipe assembly that fills a stock, e.g., the yearly amount that a government spends in excess of its revenues;
- **Stocks**: a stock can be thought of as a bathtub, e.g., the debt of a country which is the accumulation of all the previous deficits;
- **Internal feedback loops**: e.g., an increase in the amount of interest paid per year on the national debt will cause the overall national debt to increase. In the same way, an increase in the level of national debt will increase the amount of the interest paid each year;
- **Time delays**: the time lag between cause and effect.

Figure 2 shows the SD model structure with policy elements in place. Dashed arrows indicate the policy information linkages. The policy shown is a carbon tax policy that influences energy demand, and government expenditures for health and education.

For green economy policy analysis, the SD model is capable of connecting the following three dimensions of sustainable development:

- **Economic** (production and energy demand sectors);
- **Social** (population and fertility, education, roads infrastructure, health and mortality, and poverty sectors);
- **Environmental** (land-use, water demand and supply, and electricity generation and emissions sectors).

The SD component of our integrated framework focuses on green economy policy analysis. This green version of the SD model – which covers not only environmental sectors but also involves the use of a green IO-SAM - develops the sector structure needed to address the green economy policies under consideration while keeping the model flexible for interlinking with the CGE and IO components of the framework (see Figure 3).
APPLICATION OF THE IGEM FRAMEWORK

This section describes how the IGEM framework responds to major policy questions. It also presents two approaches to applying the framework.

In Figure 3, the arrows indicate the linkages between the three-component models of the integrated framework. The solid line arrows indicate explicit linkages while the dashed line arrows between the IO-SAM and SD indicate indirect linkages that occur through the CGE model. Table 4 pairs the framework’s components with the key policy questions gathered from country-level practitioners.

We can apply the framework through a target-driven or policy-driven approach. Either way, the reader will have an idea of how to implement the IGEM framework in order to answer a policy question and evaluate the impacts of a target- or policy-driven approach on the different sectors of an economy.

We should note that the illustrations below abstracts from a policy’s timing dimensions (e.g. one-time change, progressive and steady change, or change biased towards the end). In applying either approach, we should take into account this important issue.
POLICY QUESTIONS

<table>
<thead>
<tr>
<th>POLICY QUESTIONS</th>
<th>IGEM COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are the impacts (new and shifted) of policies and investments?</td>
<td>CGE  SD  IO-SAM</td>
</tr>
<tr>
<td>2. What benefits might investments and policies generate across sectors in terms</td>
<td>CGE  SD  IO-SAM</td>
</tr>
<tr>
<td>of economic opportunities, inclusiveness and environmental sustainability?</td>
<td></td>
</tr>
<tr>
<td>3. Are the impacts likely to be short- or long-term?</td>
<td>CGE  SD  IO-SAM</td>
</tr>
<tr>
<td>4. How will green subsidy reforms (e.g. feed-in tariffs) likely impact productivity in Green Economy sectors?</td>
<td>CGE  SD  IO-SAM</td>
</tr>
<tr>
<td>5. How will green tax reforms and removing fossil fuel subsidies mobilize</td>
<td>CGE  SD  IO-SAM</td>
</tr>
<tr>
<td>domestic revenues for green investment? What will be the implications of such</td>
<td></td>
</tr>
<tr>
<td>reforms on environmental, economic/fiscal and social fronts?</td>
<td></td>
</tr>
<tr>
<td>6. How do trade policies and regulations enhance investments in Green Economy</td>
<td>CGE  SD</td>
</tr>
<tr>
<td>sectors?</td>
<td></td>
</tr>
<tr>
<td>7. Which labour interventions deliver more (quantity) and better (quality</td>
<td>CGE  SD</td>
</tr>
<tr>
<td>including decency) green jobs? Which approaches create better access for the</td>
<td></td>
</tr>
<tr>
<td>unemployed and underemployed?</td>
<td></td>
</tr>
<tr>
<td>8. What types of industrial policy measures are in place to support the</td>
<td>CGE  SD</td>
</tr>
<tr>
<td>transition towards a green economy?</td>
<td></td>
</tr>
</tbody>
</table>

TARGET-DRIVEN APPROACH

A target-driven approach focuses on the outcome of a policy. In Figure 4, the desired outcome is the reduction of CO2 emissions. This outcome will serve to drive investments required to achieve it (at a level equal to the avoided cost of pollution so as to be economically efficient). In other words, the modelling constraint is set by the objective of a policy, which will then determine the means of implementation (i.e. imposing a carbon tax equal to the avoided cost of pollution, with tax revenue to be invested as required to reduce CO2 emissions).

As shown in the Figure 4, a target-driven approach could be the following: “achieve a target of an X per cent reduction of CO2 emissions by 2030 (compared to baseline year of 2015)”. We can then use this constraint to calibrate the green CGE model and the green SD model along with other assumptions. Notice that we can implement a target-driven approach by trying different investment levels and by analysing how the simulated results come closer to the specific target.

POLICY-DRIVEN APPROACH

In some cases, the modeller needs to adopt a policy-driven approach to answer the question regarding a specific policy's impacts.

As shown in Figure 5, the approach focuses on the ways of implementing a policy outcome (not necessarily quantified). The modelling constraint in this case is typically set by a financial factor (e.g. green investment, carbon tax or subsidies to renewables).
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 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.)

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)

GREEN CGE

1) Calibrate the model to include the tax rate of Y USD/tonne on CO2 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

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 CO2 emissions will be reduced and what are the health impacts
MODELLING FOR GREEN ECONOMY POLICY-MAKING: THE MEXICO CASE

Mexico is the world’s 13th largest CO2 emitter and projected to be the 5th largest economy in 2050. It introduced a carbon tax on fossil fuel production in 2014. The approximate price of carbon was set at USD3.5/tCO2eq (i.e. a policy-driven approach). Table 5 shows the different scenarios of carbon tax and how two of the integrated modelling tools (CGE and SD) can be used jointly to enrich the analysis.

Table 5  Mexico’s carbon tax: different scenarios by 2036

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>TAX RATE</th>
<th>CGE</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCENARIO 1: Feebate scenario²</td>
<td>USD3.5/tCO2eq</td>
<td>1) Estimate the economic effects of feebate scenarios compared to a rebate and a business-as-usual scenario</td>
<td>2) Estimate the social and environmental impacts resulting from the CGE simulation (health and emissions)</td>
</tr>
<tr>
<td>with low tax rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCENARIO 2: Feebate scenario</td>
<td>USD25/tCO2eq</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with high tax rate</td>
<td></td>
<td>2) Estimate the social and environmental impacts resulting from the CGE simulation (health and emissions)</td>
<td></td>
</tr>
<tr>
<td>REBATE SCENARIO:</td>
<td>USD3.5 and USD25/</td>
<td>3) Use results from the SD to estimate effects of increased longevity on productivity</td>
<td></td>
</tr>
<tr>
<td>(lump sum) with high (RH) and</td>
<td>tCO2eq</td>
<td></td>
<td></td>
</tr>
<tr>
<td>low (RL) tax rates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BUSINESS-AS-USUAL SCENARIO (BAU)</td>
<td>No carbon tax</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---


2 The word ‘feebate’ describes a system whereby energy-efficient or environmentally friendly practices receive the revenues generated from the carbon tax. In this case study, the feebate scenario includes a carbon tax that is used to subsidize the renewable energy sector. This system is opposite to a rebate system, in which revenues from the carbon tax are given back to consumers as a lump sum. However, in both cases, the carbon tax is revenue neutral. This means that the total tax collection is spent by the government, so that the fiscal position is not affected (the policy does not generate fiscal deficits or surpluses).
The following analysis (see Table 6) presents the results from running the CGE model in conjunction 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 integrated framework considers any increase in longevity equal to an increase in productivity, and uses the average longevity of Mexican workers as one metric of the carbon tax’s health impacts.

### Table 6

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>RH WITH LONGEVITY VS BAU</th>
<th>RH WITH NO LONGEVITY</th>
<th>FBH WITH NO LONGEVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>-2.5608%</td>
<td>0.3332%</td>
<td>1.2949%</td>
</tr>
<tr>
<td>INVESTMENT</td>
<td>-2.7583%</td>
<td>0.7796%</td>
<td>3.8981%</td>
</tr>
<tr>
<td>GOVERNMENT</td>
<td>-1.3718%</td>
<td>0.1916%</td>
<td>0.3705%</td>
</tr>
<tr>
<td>CAPITAL STOCK</td>
<td>-2.0615%</td>
<td>0.2945%</td>
<td>1.7113%</td>
</tr>
<tr>
<td>WELFARE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agent 1 (20% poorest)</td>
<td>-0.5612%</td>
<td>0.0614%</td>
<td>0.0709%</td>
</tr>
<tr>
<td>Agent 2 (3-5 deciles)</td>
<td>-0.8088%</td>
<td>0.0585%</td>
<td>0.0938%</td>
</tr>
<tr>
<td>Agent 1 (6-8 deciles)</td>
<td>-0.9121%</td>
<td>0.0525%</td>
<td>0.1438%</td>
</tr>
<tr>
<td>Agent 1 (20% richest)</td>
<td>-1.1663%</td>
<td>0.0533%</td>
<td>0.2468%</td>
</tr>
<tr>
<td>Aggregate welfare agents 1-4</td>
<td>-0.9912%</td>
<td>0.0545%</td>
<td>0.1786%</td>
</tr>
<tr>
<td>Government welfare</td>
<td>0.0583%</td>
<td>0.0542%</td>
<td>0.0471%</td>
</tr>
<tr>
<td>SELECTED SECTORS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>-2.2540%</td>
<td>0.5032%</td>
<td>0.4238%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-3.3250%</td>
<td>0.7797%</td>
<td>0.5180%</td>
</tr>
<tr>
<td>Oil</td>
<td>-19.4086%</td>
<td>0.3080%</td>
<td>-1.4591%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>-18.6950%</td>
<td>0.3195%</td>
<td>-1.2141%</td>
</tr>
<tr>
<td>Mining</td>
<td>-48.2412%</td>
<td>0.2921%</td>
<td>0.0974%</td>
</tr>
<tr>
<td>Refining</td>
<td>-16.7771%</td>
<td>0.3899%</td>
<td>-0.1950%</td>
</tr>
<tr>
<td>Electricity</td>
<td>-5.8425%</td>
<td>0.4676%</td>
<td>23.7461%</td>
</tr>
</tbody>
</table>
We first run each model separately and then we combine them. Both models use similar assumptions and starting points for the fee-bate scenario whereby a USD25/tCO2eq tax is levied on Mexican emissions. The CGE model gives information on the economic impact, which is in turn used by the SD model to provide results on longevity. Then, the CGE model uses these SD’s longevity results as inputs for the CGE productivity measurement.

The results indicate that in a scenario in which the two models are linked to capture the effects on longevity, GDP rises by about 1.3 percentage points more relative to when longevity gains were not taken into account. Most of this additional rise in GDP can be attributed to increased investment, which is consistent with a fee-bate policy under which carbon tax revenues are re-invested in renewable energy.

In this scenario, all consumers would experience welfare gains but the percentage gains would be slightly higher for higher income agents with capital income (agents 3 and 4). Most production sectors experience slight gains when longevity is considered, with the highest gains occurring in the electricity sector (where most carbon tax funds are re-invested). The only production sectors that show any production declines are those related to the extraction and refining of fossil fuels.

The results suggest that in the long term, a fee-bate with high carbon tax rate (USD25/tCO2eq) has a positive impact on the economic productivity and welfare at the sectoral level, particularly for the electricity sector (+23.75%). In addition, the share of renewables in total electricity generation reached in 2036 is much higher (approximately 85%). This last result highlights that productivity gains following increased longevity in the high tax fee-bate scenario result in the greatest impact for renewable energy development.

**LOOKING FORWARD**

The IGEM is the initial step we have made to integrate major modelling tools in support of policy making in the green economy space and beyond. We hope that it will provide modellers with a better framework to conduct policy analysis in a more integrated manner. The Mexican case study serves to illustrate how a combined application of different models can provide additional insights. Moving ahead, we look forward to working with interested partners to apply this framework to support policy making in specific countries.

On the technical side, we would also like to expand this framework by integrating it with additional tools such as biophysical and GIS-based models, which are critical for analysing a broader set of relationships between policies and targets concerning landscapes, biodiversity and ecosystems.
NOTES & REFERENCES


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44. UNEP (2014d), "Green Economy Assessment Study - Senegal", Geneva: UNEP.
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The Partnership supports nations and regions in reframing economic policies and practices around sustainability to foster economic growth, create income and jobs, reduce poverty and inequality, strengthen the ecological foundations of their economies and achieve the Sustainable Development Goals.

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