

The Modern Environmental Macroeconomics

George Economides

Athens University of Economics and Business, and CESifo

November 21, 2017
Rimini, Italy

Integrated Assessment Models: The Economy under Climate Change-1

- The figure below provides a depiction of climate-economy dynamics.

Integrated Assessment Models: The Economy under Climate Change-1

- The figure below provides a depiction of climate-economy dynamics.
- The climate module describes the link between GHG emission, atmospheric concentrations and the resulting variation in temperature and other climatic changes

Integrated Assessment Models: The Economy under Climate Change-1

- The figure below provides a depiction of climate-economy dynamics.
- The climate module describes the link between GHG emission, atmospheric concentrations and the resulting variation in temperature and other climatic changes
- The impacts module (or damage function) expresses physical or environmental outcomes as a function of climate variables.

Integrated Assessment Models: The Economy under Climate Change-1

- The figure below provides a depiction of climate-economy dynamics.
- The climate module describes the link between GHG emission, atmospheric concentrations and the resulting variation in temperature and other climatic changes
- The impacts module (or damage function) expresses physical or environmental outcomes as a function of climate variables.
- An economy module may describe the dynamics or growth of an economy, how emissions vary with growth and climate policies, and how climate-induced physical and environmental changes might affect parts or all of an economy.

Integrated Assessment Models: The Economy under Climate Change-1

- The figure below provides a depiction of climate-economy dynamics.
- The climate module describes the link between GHG emission, atmospheric concentrations and the resulting variation in temperature and other climatic changes
- The impacts module (or damage function) expresses physical or environmental outcomes as a function of climate variables.
- An economy module may describe the dynamics or growth of an economy, how emissions vary with growth and climate policies, and how climate-induced physical and environmental changes might affect parts or all of an economy.
- The economy model is often augmented with a more detailed energy module that describes the factors determining the uses of different sources of energy and the cost of emission reductions.

Integrated Assessment Models: The Economy under Climate Change-2

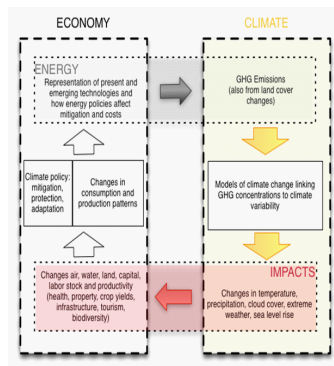


Figure 1: Climate-economy dynamics with four modules: Economy, climate, impacts, energy.

Classifying climate-economy models-1

- Optimal growth Integrated Assessment Models represent the economy as a single all encompassing sector.

Classifying climate-economy models-1

- Optimal growth Integrated Assessment Models represent the economy as a single all encompassing sector.
- Computable general equilibrium (CGE) models have a more detailed representation of the economy with multiple sectors and often include higher resolution of energy technologies and regional detail.

Classifying climate-economy models-1

- Optimal growth Integrated Assessment Models represent the economy as a single all encompassing sector.
- Computable general equilibrium (CGE) models have a more detailed representation of the economy with multiple sectors and often include higher resolution of energy technologies and regional detail.
- Partial equilibrium non-energy sector models provide a detailed analysis of the interaction between environmental impacts and a particular sector of the economy.

Classifying climate-economy models-2

- Energy systems models are partial equilibrium models that provide a detailed account of energy technologies and their associated costs.

Classifying climate-economy models-2

- Energy systems models are partial equilibrium models that provide a detailed account of energy technologies and their associated costs.
- Macroeconometric models like computable general equilibrium models can be quite detailed in terms of energy technologies and geographic scope and are also used to evaluate alternative climate policies but they differ in that they do not assume that consumers and producers behave optimally or that markets clear.

Classifying climate-economy models-2

- Energy systems models are partial equilibrium models that provide a detailed account of energy technologies and their associated costs.
- Macroeconometric models like computable general equilibrium models can be quite detailed in terms of energy technologies and geographic scope and are also used to evaluate alternative climate policies but they differ in that they do not assume that consumers and producers behave optimally or that markets clear.
- Other Integrated Assessment Models refers to models that may have little in common except that they do not fit neatly into any of the previous well known groups.

The most important Integrated Assessment Models (Gillingham et al. (2015))-1

- the DICE (Dynamic Integrated model of Climate and the Economy) model

The most important Integrated Assessment Models (Gillingham et al. (2015))-1

- the DICE (Dynamic Integrated model of Climate and the Economy) model
 - It was first developed around 1990 and has gone through several extensions and revisions. The latest published version is Nordhaus (2014) with a detailed description in Nordhaus and Sztorc (2014).

The most important Integrated Assessment Models (Gillingham et al. (2015))-1

- the DICE (Dynamic Integrated model of Climate and the Economy) model
 - It was first developed around 1990 and has gone through several extensions and revisions. The latest published version is Nordhaus (2014) with a detailed description in Nordhaus and Sztorc (2014).
 - It is a globally aggregated model that views the economics of climate change from the perspective of neoclassical economic growth theory.

The most important Integrated Assessment Models (Gillingham et al. (2015))-1

- the DICE (Dynamic Integrated model of Climate and the Economy) model
 - It was first developed around 1990 and has gone through several extensions and revisions. The latest published version is Nordhaus (2014) with a detailed description in Nordhaus and Sztorc (2014).
 - It is a globally aggregated model that views the economics of climate change from the perspective of neoclassical economic growth theory.
 - In this approach, economies make investments in capital and in emissions reductions, reducing consumption today, in order to lower climate damages and increase consumption in the future.

The most important Integrated Assessment Models (Gillingham et al. (2015))-1

- the DICE (Dynamic Integrated model of Climate and the Economy) model
 - It was first developed around 1990 and has gone through several extensions and revisions. The latest published version is Nordhaus (2014) with a detailed description in Nordhaus and Sztorc (2014).
 - It is a globally aggregated model that views the economics of climate change from the perspective of neoclassical economic growth theory.
 - In this approach, economies make investments in capital and in emissions reductions, reducing consumption today, in order to lower climate damages and increase consumption in the future.
 - The special feature of the model is the inclusion of all major elements in a highly aggregated fashion.

The most important Integrated Assessment Models (Gillingham et al. (2015))-1

- the DICE (Dynamic Integrated model of Climate and the Economy) model
 - It was first developed around 1990 and has gone through several extensions and revisions. The latest published version is Nordhaus (2014) with a detailed description in Nordhaus and Sztorc (2014).
 - It is a globally aggregated model that views the economics of climate change from the perspective of neoclassical economic growth theory.
 - In this approach, economies make investments in capital and in emissions reductions, reducing consumption today, in order to lower climate damages and increase consumption in the future.
 - The special feature of the model is the inclusion of all major elements in a highly aggregated fashion.
 - The model contains about 25 dynamic equations and identities, including those for global output, CO₂ emissions and concentrations, global mean temperature, and damages.

The most important Integrated Assessment Models (Gillingham et al. (2015))-2

- the FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model

The most important Integrated Assessment Models (Gillingham et al. (2015))-2

- the FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model
 - was developed primarily to assess the impacts of climate policies in an integrated framework.

The most important Integrated Assessment Models (Gillingham et al. (2015))-2

- the FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model
 - was developed primarily to assess the impacts of climate policies in an integrated framework.
 - It is a recursive model that takes exogenous scenarios of major economic variables as inputs and then perturbs these with estimates of the cost of climate policy and the impacts of climate change.

The most important Integrated Assessment Models (Gillingham et al. (2015))-2

- the FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model
 - was developed primarily to assess the impacts of climate policies in an integrated framework.
 - It is a recursive model that takes exogenous scenarios of major economic variables as inputs and then perturbs these with estimates of the cost of climate policy and the impacts of climate change.
 - The model has 16 regions and contains explicit representation of five greenhouse gases.

The most important Integrated Assessment Models (Gillingham et al. (2015))-2

- the FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model
 - was developed primarily to assess the impacts of climate policies in an integrated framework.
 - It is a recursive model that takes exogenous scenarios of major economic variables as inputs and then perturbs these with estimates of the cost of climate policy and the impacts of climate change.
 - The model has 16 regions and contains explicit representation of five greenhouse gases.
 - Climate change impacts are monetized and include agriculture, forestry, sea-level rise, health impacts, energy consumption, water resources, unmanaged ecosystems, and storm impacts.

The most important Integrated Assessment Models (Gillingham et al. (2015))-2

- the FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model
 - was developed primarily to assess the impacts of climate policies in an integrated framework.
 - It is a recursive model that takes exogenous scenarios of major economic variables as inputs and then perturbs these with estimates of the cost of climate policy and the impacts of climate change.
 - The model has 16 regions and contains explicit representation of five greenhouse gases.
 - Climate change impacts are monetized and include agriculture, forestry, sea-level rise, health impacts, energy consumption, water resources, unmanaged ecosystems, and storm impacts.
 - Each impact sector has a different functional form and is calculated separately for each of the 16 regions. The model runs from 1950 to 3000 in time steps of 1 year.

The most important Integrated Assessment Models (Gillingham et al. (2015))-3

- the GCAM (Global Change Assessment Model) model

The most important Integrated Assessment Models (Gillingham et al. (2015))-3

- the GCAM (Global Change Assessment Model) model
 - It is a global integrated assessment model of energy, economy, land-use, and climate.

The most important Integrated Assessment Models (Gillingham et al. (2015))-3

- the GCAM (Global Change Assessment Model) model
 - It is a global integrated assessment model of energy, economy, land-use, and climate.
 - It is a long-term global model based on the Edmonds and Reilly model (Edmonds and Reilly, 1983a,b,c).

The most important Integrated Assessment Models (Gillingham et al. (2015))-3

- the GCAM (Global Change Assessment Model) model
 - It is a global integrated assessment model of energy, economy, land-use, and climate.
 - It is a long-term global model based on the Edmonds and Reilly model (Edmonds and Reilly, 1983a,b,c).
 - GCAM integrates representations of the global economy, energy systems, agriculture and land use, with representations of terrestrial and ocean carbon cycles, and a suite of coupled gas-cycle and climate models.

The most important Integrated Assessment Models (Gillingham et al. (2015))-3

- the GCAM (Global Change Assessment Model) model
 - It is a global integrated assessment model of energy, economy, land-use, and climate.
 - It is a long-term global model based on the Edmonds and Reilly model (Edmonds and Reilly, 1983a,b,c).
 - GCAM integrates representations of the global economy, energy systems, agriculture and land use, with representations of terrestrial and ocean carbon cycles, and a suite of coupled gas-cycle and climate models.
 - The climate and physical atmosphere in GCAM is based on the Model for the Assessment of Greenhouse-Gas Induced Climate Change (MAGICC) (Meinshausen et al., 2011).

The most important Integrated Assessment Models (Gillingham et al. (2015))-3

- the GCAM (Global Change Assessment Model) model
 - It is a global integrated assessment model of energy, economy, land-use, and climate.
 - It is a long-term global model based on the Edmonds and Reilly model (Edmonds and Reilly, 1983a,b,c).
 - GCAM integrates representations of the global economy, energy systems, agriculture and land use, with representations of terrestrial and ocean carbon cycles, and a suite of coupled gas-cycle and climate models.
 - The climate and physical atmosphere in GCAM is based on the Model for the Assessment of Greenhouse-Gas Induced Climate Change (MAGICC) (Meinshausen et al., 2011).
 - The global economy in GCAM is represented in 14 geopolitical regions.

The most important Integrated Assessment Models (Gillingham et al. (2015))-3

- the GCAM (Global Change Assessment Model) model
 - It is a global integrated assessment model of energy, economy, land-use, and climate.
 - It is a long-term global model based on the Edmonds and Reilly model (Edmonds and Reilly, 1983a,b,c).
 - GCAM integrates representations of the global economy, energy systems, agriculture and land use, with representations of terrestrial and ocean carbon cycles, and a suite of coupled gas-cycle and climate models.
 - The climate and physical atmosphere in GCAM is based on the Model for the Assessment of Greenhouse-Gas Induced Climate Change (MAGICC) (Meinshausen et al., 2011).
 - The global economy in GCAM is represented in 14 geopolitical regions.
 - The model is dynamic-recursively solved for a set of market-clearing equilibrium prices in all energy and agricultural good markets every 5 years over 2005–2095.

The most important Integrated Assessment Models (Gillingham et al. (2015))-4

- the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies) model

The most important Integrated Assessment Models (Gillingham et al. (2015))-4

- the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies) model
 - It is an integrated assessment model describing global energy-economy-climate interactions with regional detail.

The most important Integrated Assessment Models (Gillingham et al. (2015))-4

- the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies) model
 - It is an integrated assessment model describing global energy-economy-climate interactions with regional detail.
 - MERGE is formulated as a multi-region dynamic general equilibrium model with a process model of the energy system and a reduced-form representation of the climate.

The most important Integrated Assessment Models (Gillingham et al. (2015))-4

- the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies) model
 - It is an integrated assessment model describing global energy-economy-climate interactions with regional detail.
 - MERGE is formulated as a multi-region dynamic general equilibrium model with a process model of the energy system and a reduced-form representation of the climate.
 - It is solved in GAMS via sequential joint non-linear optimization with Negishi weights to balance inter-regional trade flows.

The most important Integrated Assessment Models (Gillingham et al. (2015))-4

- the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies) model
 - It is an integrated assessment model describing global energy-economy-climate interactions with regional detail.
 - MERGE is formulated as a multi-region dynamic general equilibrium model with a process model of the energy system and a reduced-form representation of the climate.
 - It is solved in GAMS via sequential joint non-linear optimization with Negishi weights to balance inter-regional trade flows.
 - The economy is represented as a top-down Ramsey model in which electric and non-electric energy inputs are traded off against capital and labor and production is allocated between consumption and investment.

The most important Integrated Assessment Models (Gillingham et al. (2015))-4

- the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies) model
 - It is an integrated assessment model describing global energy-economy-climate interactions with regional detail.
 - MERGE is formulated as a multi-region dynamic general equilibrium model with a process model of the energy system and a reduced-form representation of the climate.
 - It is solved in GAMS via sequential joint non-linear optimization with Negishi weights to balance inter-regional trade flows.
 - The economy is represented as a top-down Ramsey model in which electric and non-electric energy inputs are traded off against capital and labor and production is allocated between consumption and investment.
 - The climate model includes a five-box carbon cycle and tracks all major non-CO2 greenhouse gases and non-CO2 forcing agents explicitly.

The most important Integrated Assessment Models (Gillingham et al. (2015))-4

- the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gas reduction policies) model
 - It is an integrated assessment model describing global energy-economy-climate interactions with regional detail.
 - MERGE is formulated as a multi-region dynamic general equilibrium model with a process model of the energy system and a reduced-form representation of the climate.
 - It is solved in GAMS via sequential joint non-linear optimization with Negishi weights to balance inter-regional trade flows.
 - The economy is represented as a top-down Ramsey model in which electric and non-electric energy inputs are traded off against capital and labor and production is allocated between consumption and investment.
 - The climate model includes a five-box carbon cycle and tracks all major non-CO2 greenhouse gases and non-CO2 forcing agents explicitly.
 - Temperature evolves as a two-box lag process, where uncertainty about climate sensitivity is considered jointly with uncertainty about the response time and aerosol forcing.

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model
 - It was developed in the early 1990's and has been continually updated.

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model
 - It was developed in the early 1990's and has been continually updated.
 - It includes a general circulation model of the atmosphere and its interactions with oceans, atmospheric chemistry, terrestrial vegetation, and the land surface.

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model
 - It was developed in the early 1990's and has been continually updated.
 - It includes a general circulation model of the atmosphere and its interactions with oceans, atmospheric chemistry, terrestrial vegetation, and the land surface.
 - Its economic component represents the economy and anthropogenic emissions.

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model
 - It was developed in the early 1990's and has been continually updated.
 - It includes a general circulation model of the atmosphere and its interactions with oceans, atmospheric chemistry, terrestrial vegetation, and the land surface.
 - Its economic component represents the economy and anthropogenic emissions.
 - The full IGSM is described in Sokolov et al. (2009) and Webster et al. (2012).

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model
 - It was developed in the early 1990's and has been continually updated.
 - It includes a general circulation model of the atmosphere and its interactions with oceans, atmospheric chemistry, terrestrial vegetation, and the land surface.
 - Its economic component represents the economy and anthropogenic emissions.
 - The full IGSM is described in Sokolov et al. (2009) and Webster et al. (2012).
 - The earth system component is a simplified general circulation model resolved in 46 latitude bands and 11 vertical layers in the atmosphere with an 11-layer ocean model.

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model
 - It was developed in the early 1990's and has been continually updated.
 - It includes a general circulation model of the atmosphere and its interactions with oceans, atmospheric chemistry, terrestrial vegetation, and the land surface.
 - Its economic component represents the economy and anthropogenic emissions.
 - The full IGSM is described in Sokolov et al. (2009) and Webster et al. (2012).
 - The earth system component is a simplified general circulation model resolved in 46 latitude bands and 11 vertical layers in the atmosphere with an 11-layer ocean model.
 - The land system includes 17 vegetation types.

The most important Integrated Assessment Models (Gillingham et al. (2015))-5

- the MIT IGSM (Integrated Global Systems Model) model
 - It was developed in the early 1990's and has been continually updated.
 - It includes a general circulation model of the atmosphere and its interactions with oceans, atmospheric chemistry, terrestrial vegetation, and the land surface.
 - Its economic component represents the economy and anthropogenic emissions.
 - The full IGSM is described in Sokolov et al. (2009) and Webster et al. (2012).
 - The earth system component is a simplified general circulation model resolved in 46 latitude bands and 11 vertical layers in the atmosphere with an 11-layer ocean model.
 - The land system includes 17 vegetation types.
 - The economic component is a multi-sector, multi-region applied general equilibrium model, an empirical implementation consistent with neo-classical economic theory.

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model
 - It was developed in 2006 (Bosetti et al., 2006) and has been developed and extended since then.

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model
 - It was developed in 2006 (Bosetti et al., 2006) and has been developed and extended since then.
 - The latest version is fully described in Bosetti et al. (2014).

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model
 - It was developed in 2006 (Bosetti et al., 2006) and has been developed and extended since then.
 - The latest version is fully described in Bosetti et al. (2014).
 - The model divides the world into 13 major regions.

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model
 - It was developed in 2006 (Bosetti et al., 2006) and has been developed and extended since then.
 - The latest version is fully described in Bosetti et al. (2014).
 - The model divides the world into 13 major regions.
 - The economy of each region is described by a Ramsey-type neoclassical optimal growth model, where forward-looking central planners maximize the present discounted value of utility of each region.

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model
 - It was developed in 2006 (Bosetti et al., 2006) and has been developed and extended since then.
 - The latest version is fully described in Bosetti et al. (2014).
 - The model divides the world into 13 major regions.
 - The economy of each region is described by a Ramsey-type neoclassical optimal growth model, where forward-looking central planners maximize the present discounted value of utility of each region.
 - These optimizations take account of other regions' intertemporal strategies.

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model
 - It was developed in 2006 (Bosetti et al., 2006) and has been developed and extended since then.
 - The latest version is fully described in Bosetti et al. (2014).
 - The model divides the world into 13 major regions.
 - The economy of each region is described by a Ramsey-type neoclassical optimal growth model, where forward-looking central planners maximize the present discounted value of utility of each region.
 - These optimizations take account of other regions' intertemporal strategies.
 - The optimal investment strategy includes a detailed appraisal of energy sector investments in power-generation technologies and innovation, and the direct consumption of fuels, as well as abatement of other gases and land-use emissions.

The most important Integrated Assessment Models (Gillingham et al. (2015))-6

- the WITCH (World Induced Technical Change Hybrid) model
 - It was developed in 2006 (Bosetti et al., 2006) and has been developed and extended since then.
 - The latest version is fully described in Bosetti et al. (2014).
 - The model divides the world into 13 major regions.
 - The economy of each region is described by a Ramsey-type neoclassical optimal growth model, where forward-looking central planners maximize the present discounted value of utility of each region.
 - These optimizations take account of other regions' intertemporal strategies.
 - The optimal investment strategy includes a detailed appraisal of energy sector investments in power-generation technologies and innovation, and the direct consumption of fuels, as well as abatement of other gases and land-use emissions.
 - Greenhouse-gas emissions and concentrations are then used as inputs in a climate model of reduced complexity (Meinshausen et al., 2011).