Using **Genuine Savings** for climate policy evaluation with an integrated assessement model

For ETSAP meeting

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Presentation structure

1. What is “Genuine Savings”
2. Model
   - Criticism on climate-economy IAM
   - Our innovation
   - Comparisons with other approaches
3. Example of Results
4. Summary

3 Details are in DP from St. Andrews

University of St. Andrews

Discussion papers in Environmental Economics

http://www.st-andrews.ac.uk/gsd/research/envecon/eediscus/

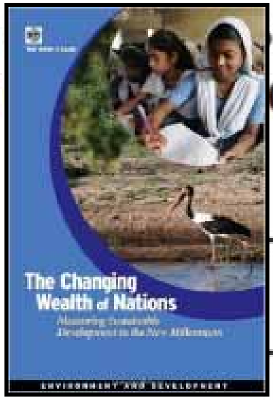
Paper 2017-07

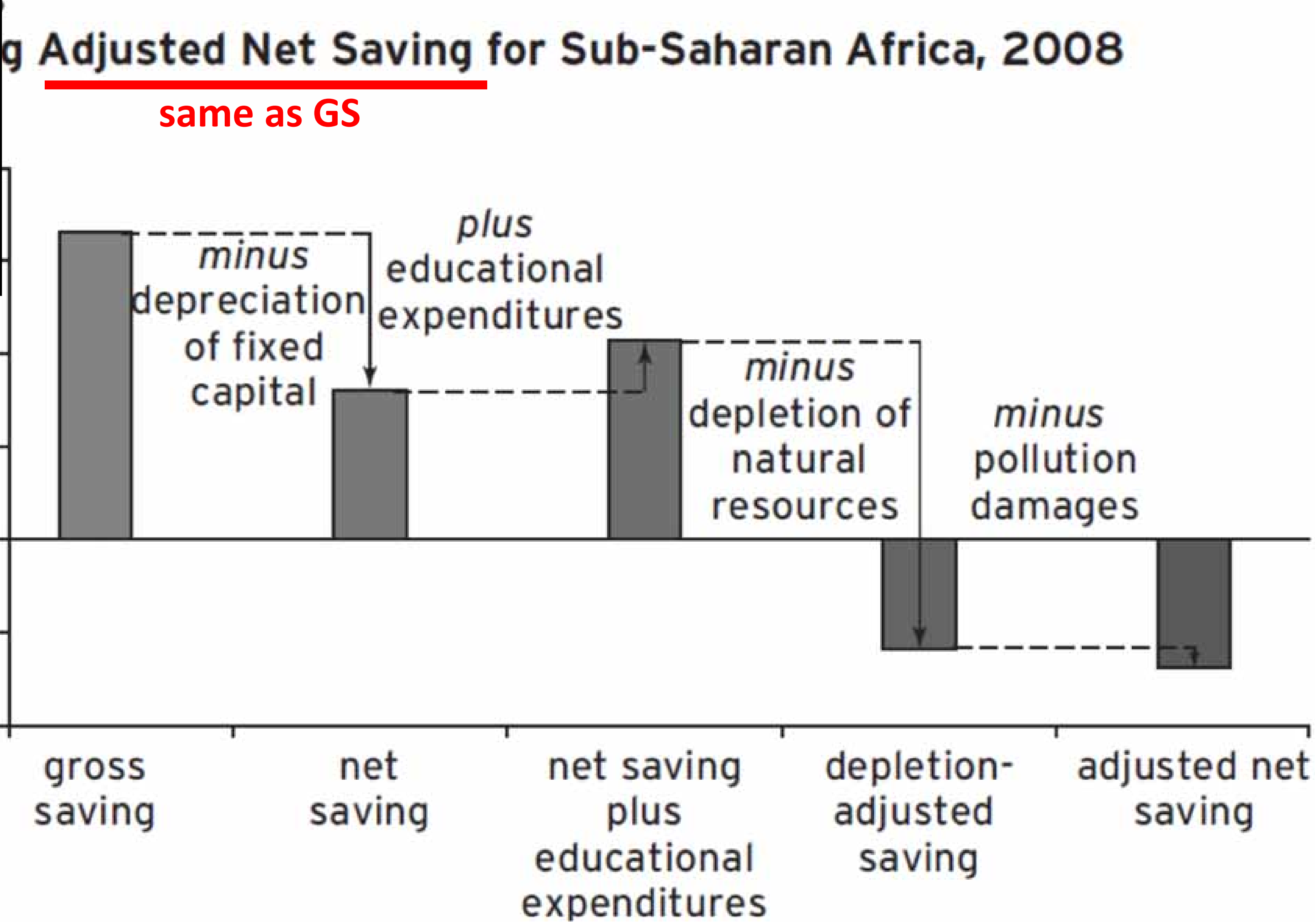
Using Genuine Savings for Climate Policy Evaluation with an Integrated Assessment Model

L. Dupuy, K. Tokimatsu, and N. Hanley

The World Bank 2011

"The changing wealth of nations: measuring sustainable development in the new millennium"
http://siteresources.worldbank.org/ENVIRONMENT/Resources/ChangingWealthNations.pdf.





Difinition of GS/IW

- **The theory of Genuine Savings (or Adjusted Net Savings) :**
  - ***Sustainability as non declining well-being over time***

$$V_t = \int_t^{\infty} U_t C(s) e^{-\rho(s-t)} ds$$

  - ***Asset and consumption mapping through an economic program***

$$E(s)_t = \{C(s), K(s), H(s), N(s), I(s)_K, I(s)_H, I(s)_N\}_t$$

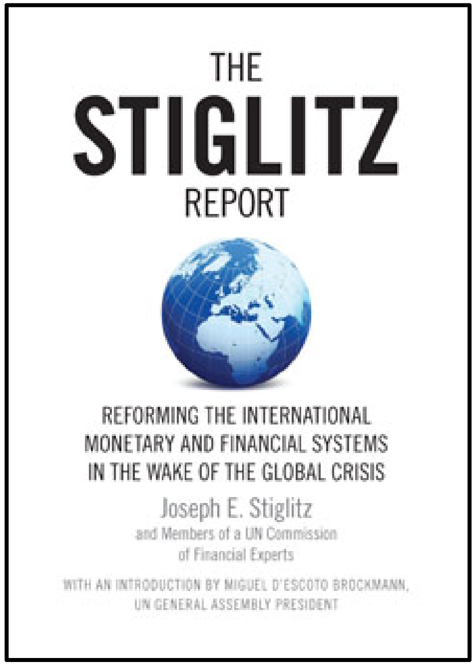
  - ***SD indicator since rate of change in wealth = rate of change in instantaneous well-being***
  - ***Definition of Comprehensive/Inclusive Wealth***

$$W_t = p_t K_t + w_t H_t + n_t N_t$$

  - ***GS as the rate of change in total wealth at shadow prices***

$$GS_t = p_t \frac{dK_t}{dt} + w_t \frac{dH_t}{dt} + n_t \frac{dN_t}{dt}$$

6 Beyond GDP: Proposals for alternative measurement tools

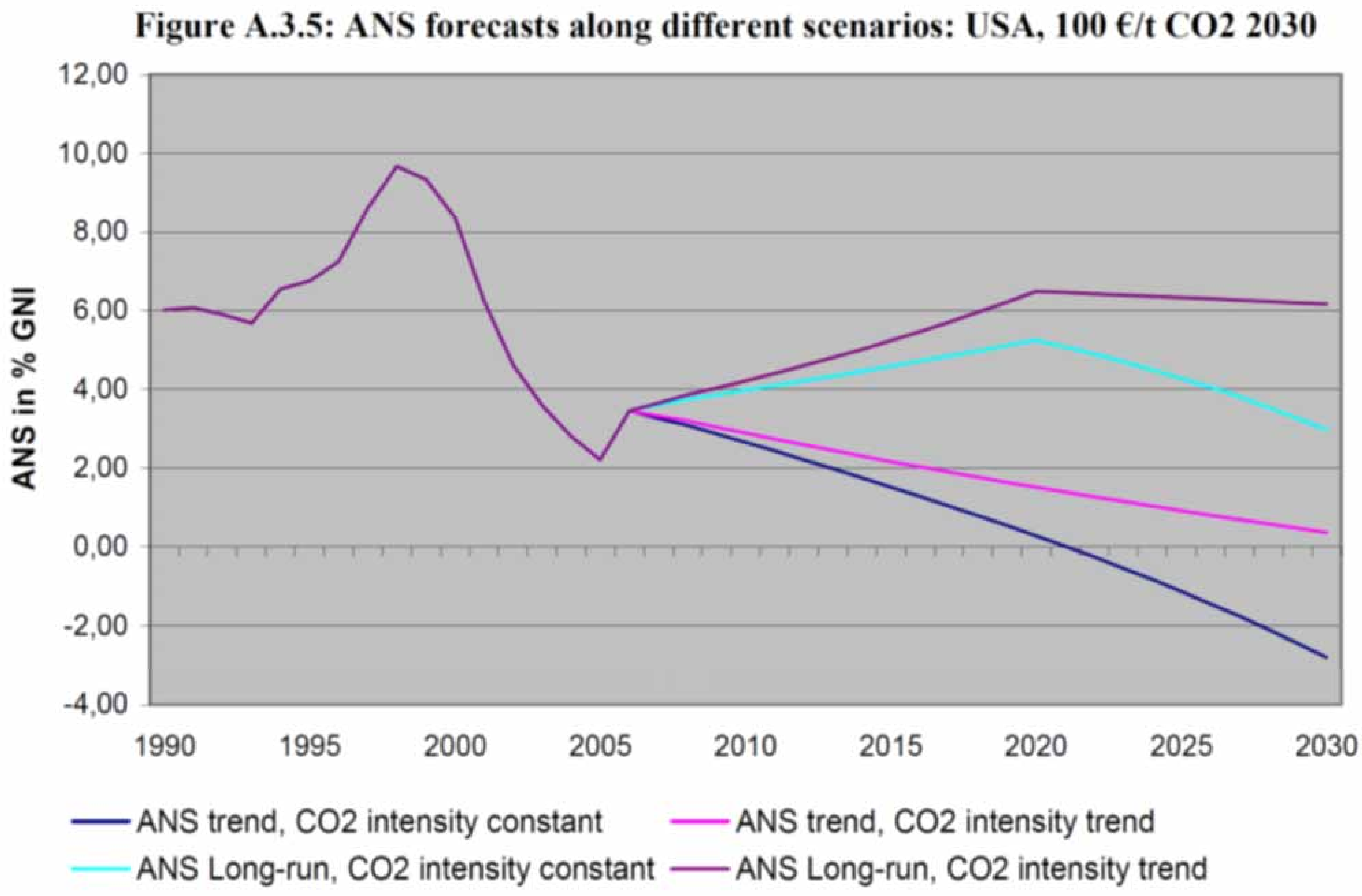


The Stiglitz Commission Report makes 12 recommendations on moving from production to well-being. These range from including measures of income, consumption, and wealth – both market and non-market, as well as their overall distribution – to objective and subjective measures of well-being, such as health, education, personal activities, and environmental conditions.

The European Commission, which has worked on the issue for a decade, has outlined a roadmap for new indicators that includes up-to-date measures on environmental protection and quality of life; distribution between income, health, education, and environmental quality; overall sustainability; and social issues.

Source: http://www3.weforum.org/docs/WEF_Forum_IncGrwth_2017.pdf

Stiglitz Report 2009



1. State of the art IAM approach

(1) highly aggregated, algebraic damage function

- the modeller's choice of a particular algebraic formula
- the common assumption of zero damage at the origin
- the modeller's estimate of damages at a benchmark change

$$D(T) = 1/\left[1 + \pi_1(T) + \pi_2(T)^2\right]$$

Pindyck 2013 criticized that

- ***completely made up, with no theoretical or empirical foundation.***
- ***choice of values for these parameters is essentially guess work.***
- ***Nordhaus "global mean losses could be 1-5 percent of GDP for 4℃ of warming"…From its own survey of several IAMs. it's a bit circular.***

IPCC AR5 (WG3, 3.9.2 Aggregate climate damages)

- ***A concern may be whether the curvature … is adequate.***
- ***The aggregated damage is … heroic extrapolations to … global scale from a sparse set of studies … done at particular geographic locations.***

Our strategy – interlinking our LCIA model

$$D(T) = 1/\left[1 + \pi_1(T) + \pi_2(T)^2\right] \qquad Y = D(T)\cdot F(K,L)$$

$$Y = F(K, H, EL, NE, M, LR) - TC - EXT$$

$$EXT_{rg,yr} = \sum_{ep} MWTP_{ep,rg,yr} \cdot \sum_{sbs} DR_{ep,sbs,rg,yr} \cdot Inv_{sbs,rg,yr}$$

Environmental external cost | **marginal willingness to pay** | **Dose-Response relations** | **Inventory release**

ep： end points (human health, resources, biodiversity, photosynthetic NPP)
sbs：global warming, ozone layer depletion, acid rain, local air pollution, mining and disposal of mineral resources, land use and its change

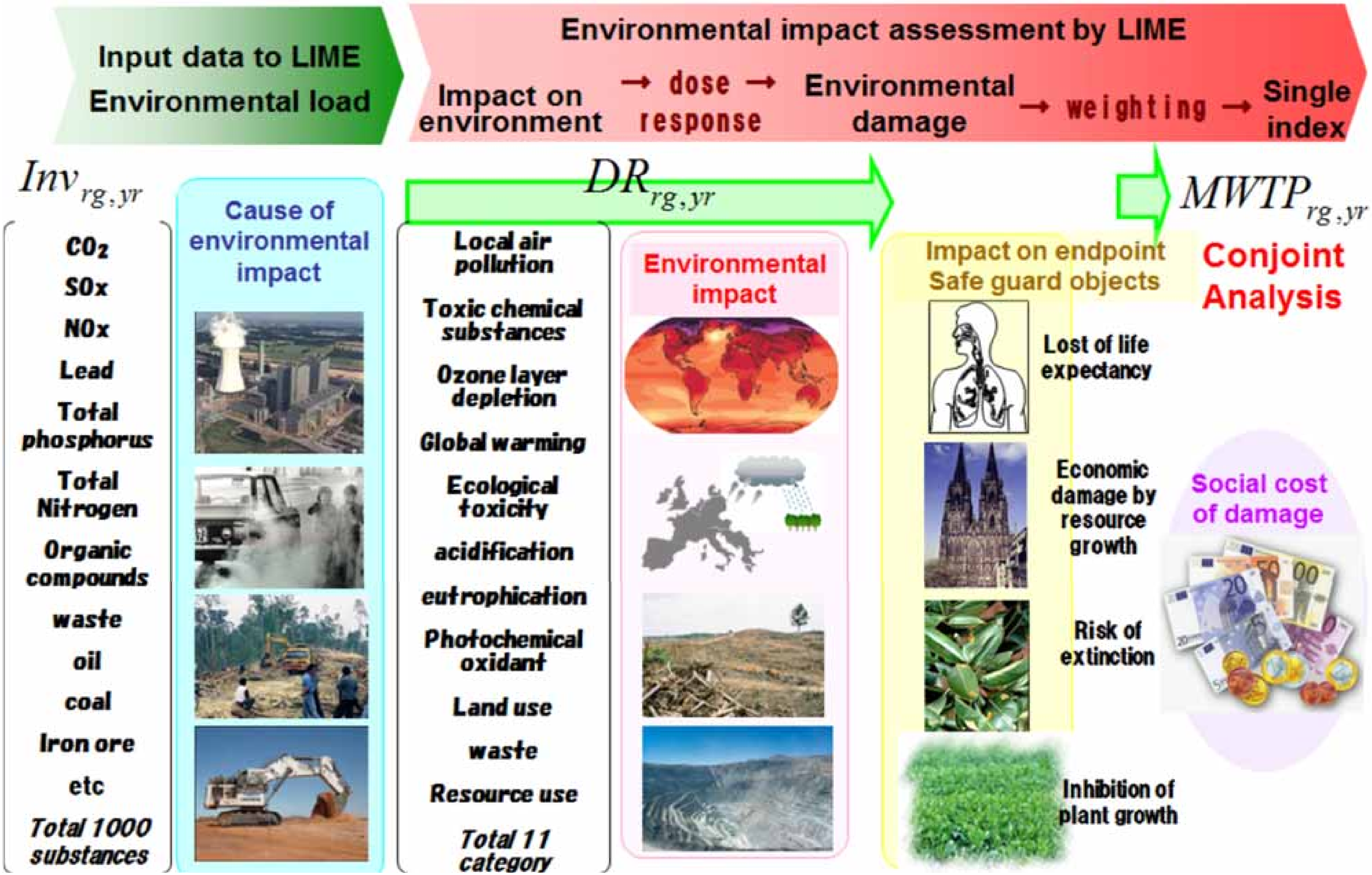
- **face to face, internet**
- **G20+10 Asian**
- **over 7,800ss, 100 (min) to 600 (max)**

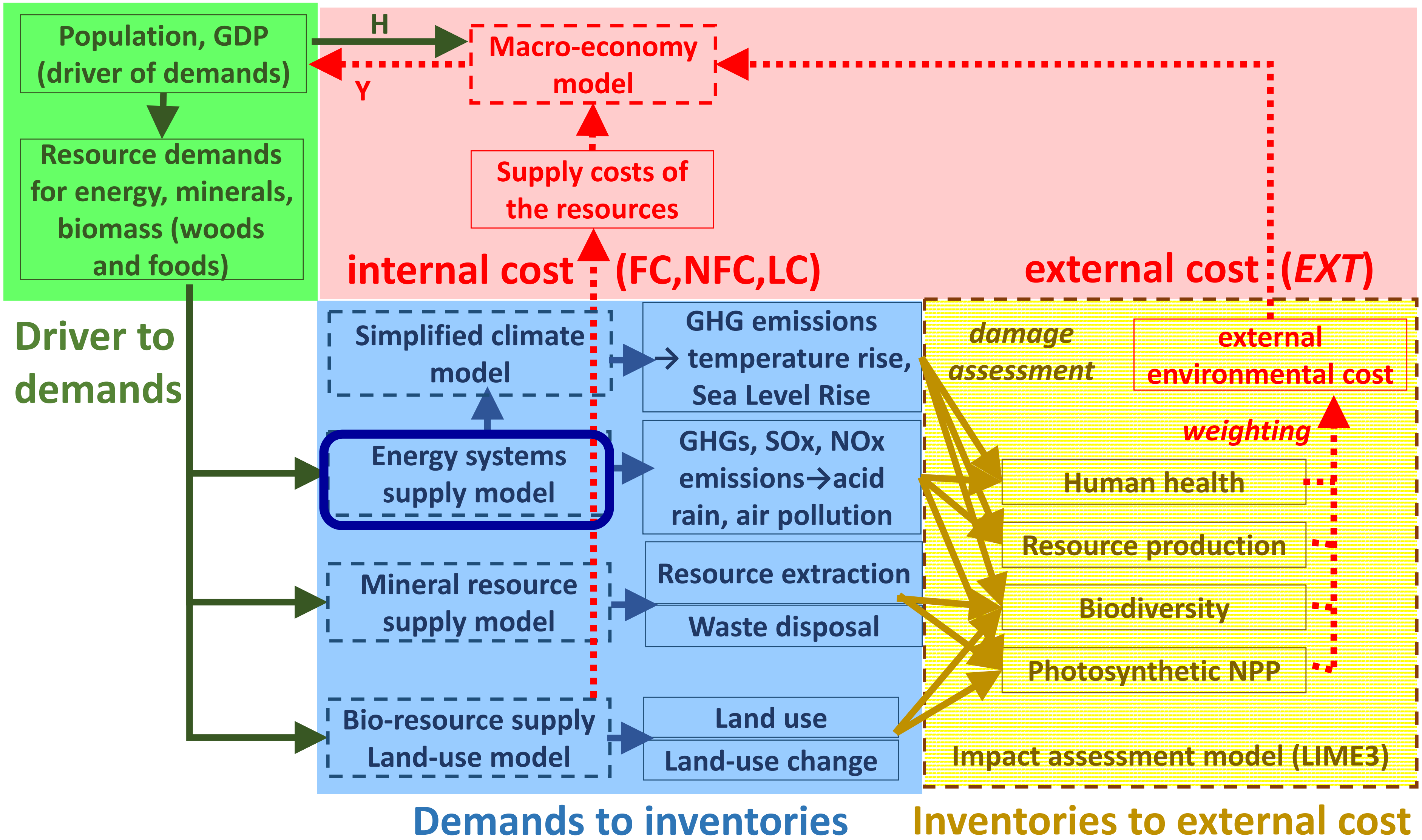
Y: GDP
N: population number
σ: income elasticity

$$\begin{cases} MWTP_{ep,rg,yr} = MWTP_{ep,rg_0,yr_0} \cdot \left(\dfrac{Y_{rg,yr} / N_{rg,yr}}{Y_{rg_0,yr_0} / N_{rg_0,yr_0}} \right)^{\sigma_{ep}} \\ MWTP_{ep,rg,yr} = \sum_i a_{i,ep} x_{i,rg,yr} + dummy_{ep} \end{cases}$$

10 Japanese version of lifecycle impact assessment modeling (LIME)

$$EXT_{rg,yr} = \sum_{ep} MWTP_{ep,rg,yr} \cdot \sum_{sbs} DR_{ep,sbs,rg,yr} \cdot Inv_{sbs,rg,yr}$$





$$Max \quad W \equiv \sum\nolimits_{rg} Neg_{rg} V_{rg}$$

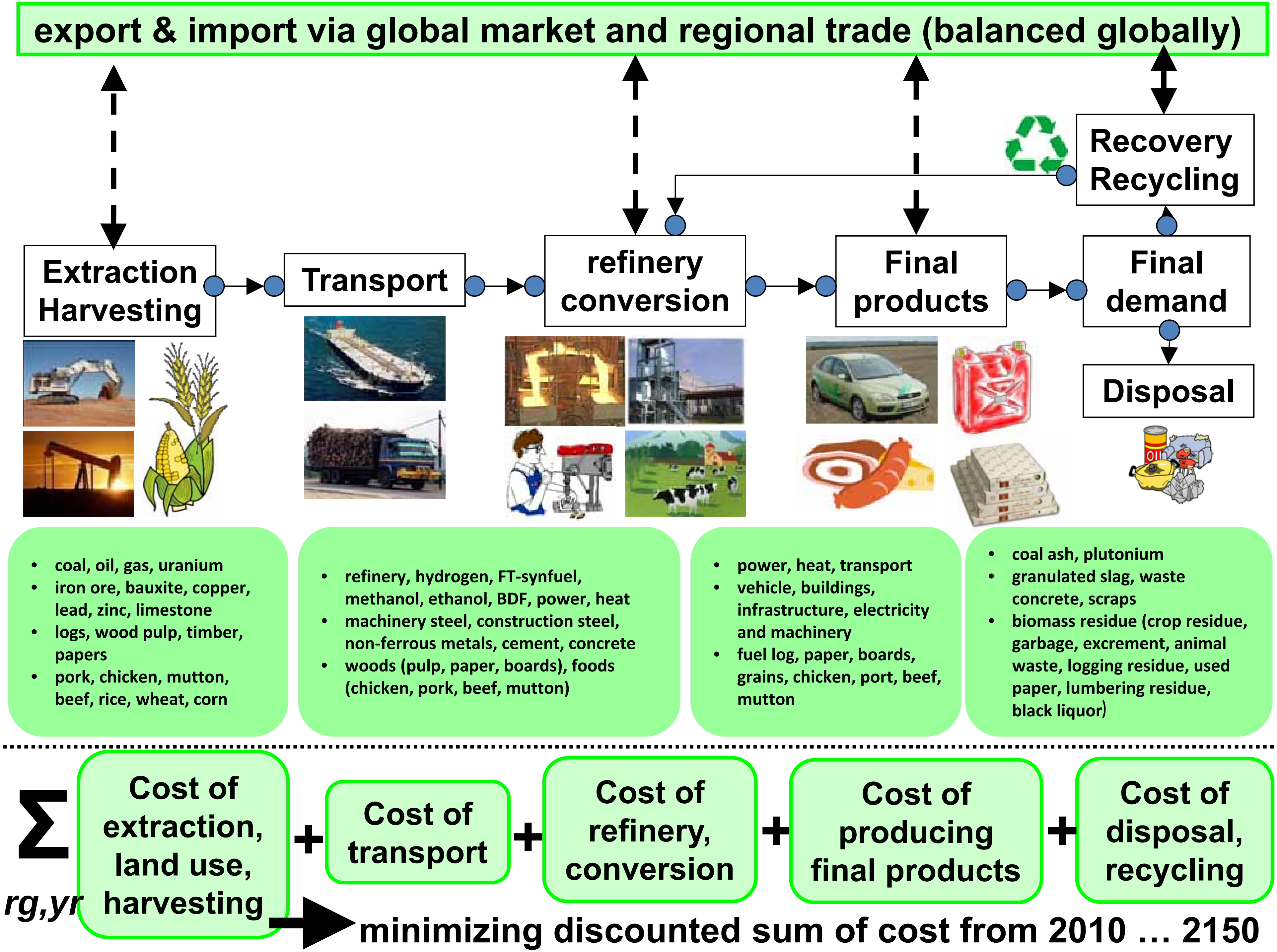
$$V_{rg} = \sum\nolimits_{\xi=0}^{14} \left(\frac{1}{1+\rho} \right)^{\xi} \cdot N_{rg,2010+10\xi} \cdot u_{rg,2010+10\xi}$$

$$u_{rg,yr} \equiv \begin{cases} \dfrac{c_{rg,yr}{}^{1-\eta}}{1-\eta} & (\eta \neq 1) \\ \log c_{rg,yr} & (\eta = 1) \end{cases}$$

$$Y_{rg,yr} = C_{rg,yr} + I_{rg,yr} + IM_{rg,yr} - XP_{rg,yr}$$

From inventories release to damages in our model

input data from other models to the impact assessment model	Model name	Contents of the impact assessment model: Impact category	endpoints	
global mean temperature rise (endogenous)	Simplified climate model	Global warming	Human health	Heart disease, diarrhea, malnutrition, flood, malaria
			resources	Crop yield (rice, corn, wheat)
				Sea level rise (flooded surface)
				Energy consumption (cooling, warming for air conditioning)
			biodiversity	
Ozone Depletion Substances (14 kinds) (exogenous)	Simplified climate model	Ozone layer depletion	Human health, resources, net *photosynthetic* primary productivity (NPP)	
SO_X, NOx (endogenous)	Energy model	Acid rain	resources	
		Local air pollution	Human health, resources, NPP	
Land use (endogenous)	Bio resource and land use model	Land use	NPP	
Land-use change (endogenous)	Bio resource and land use model	Land use change	NPP, biodiversity	
Copper, lead, zinc, bauxite, iron ore, limestone, coal (endogenous)	Mineral resource model	Resource extraction	NPP, biodiversity	
Mineral resource waste, scrap of concrete (endogenous)	Mineral resource model	waste	NPP, biodiversity	



export & import via global market and regional trade (balanced globally)
Recovery Recycling
Extraction Harvesting
Transport
refinery conversion
Final products
Final demand
Disposal
• coal, oil, gas, uranium
• iron ore, bauxite, copper, lead, zinc, limestone
• logs, wood pulp, timber, papers
• pork, chicken, mutton, beef, rice, wheat, corn
• refinery, hydrogen, FT-synfuel, methanol, ethanol, BDF, power, heat
• machinery steel, construction steel, non-ferrous metals, cement, concrete
• woods (pulp, paper, boards), foods (chicken, pork, beef, mutton)
• power, heat, transport
• vehicle, buildings, infrastructure, electricity and machinery
• fuel log, paper, boards, grains, chicken, port, beef, mutton
• coal ash, plutonium
• granulated slag, waste concrete, scraps
• biomass residue (crop residue, garbage, excrement, animal waste, logging residue, used paper, lumbering residue, black liquor)
Σ rg,yr
Cost of extraction, land use, harvesting
+
Cost of transport
+
Cost of refinery, conversion
+
Cost of producing final products
+
Cost of disposal, recycling
minimizing discounted sum of cost from 2010 … 2150

What models can do for sustainability/SD issues

1 or 3 models

Energy (or mineral) model (+ climate)

3 resource models (+climate)

targets
- resource needs
- climate change mitigation (energy conversion tech.)
- ore degradation (scarce base metal e.g., copper)

SD indicators
- Factor-4 (resource productivity or decoupling)
- Factor-10 (fairness in per capita material consumption)

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5 models = Full - econ

3 resources + climate

+ LCA model (LIME3)

targets
- external environmental impacts and their costs

SD indicators
- Eco-Efficiency = GDP/Externality
- Human Appropriated Net Primary Productivity (HANPP) = carrying capacity

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Full models

3 resources + climate

+ LCA model (LIME3)

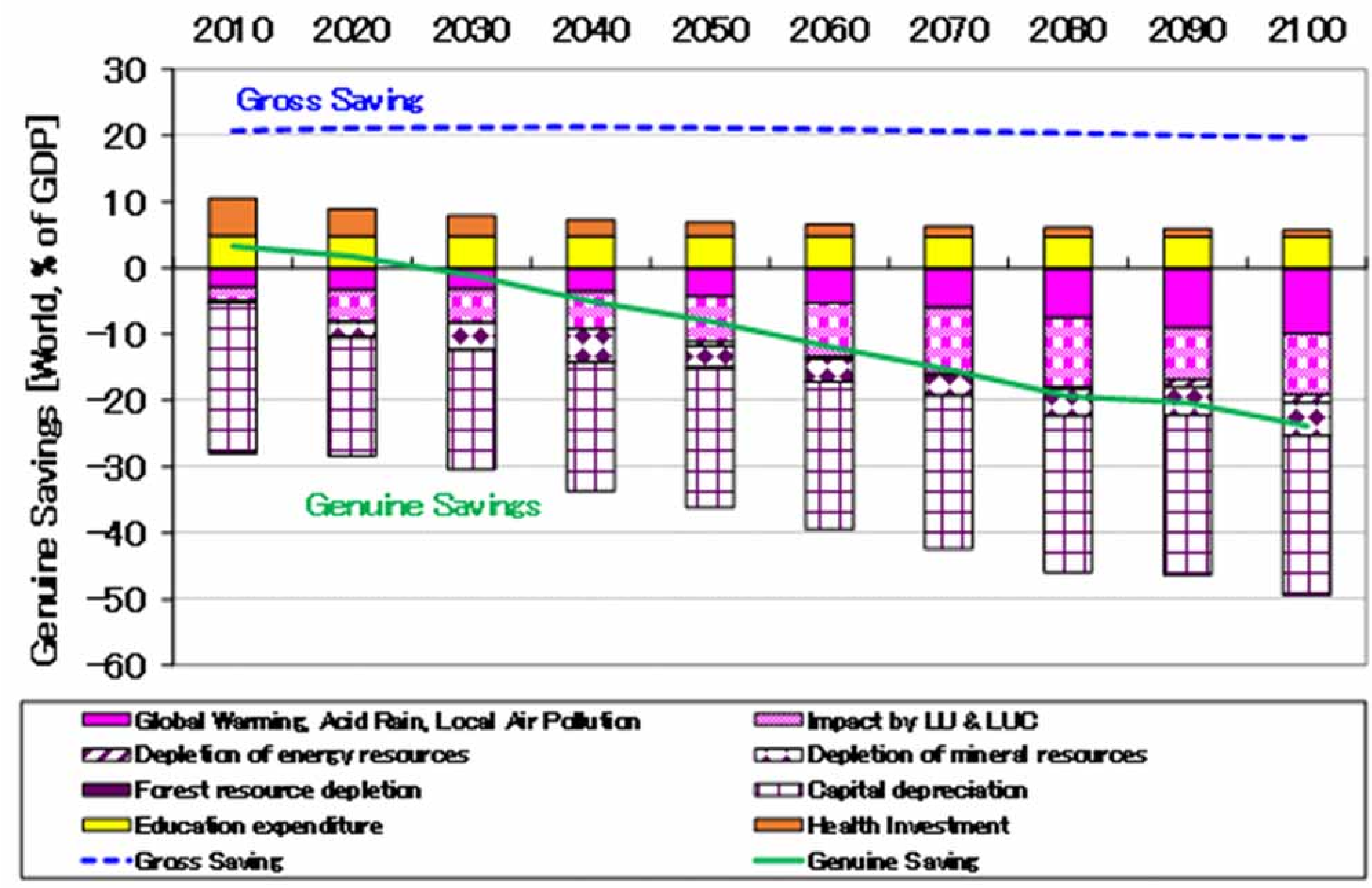
econ (util & prod. func)

targets
- cost-benefit; internalizing the externalities (e.g.CC&M)
- alternative shadow price of carbon (or SCC)

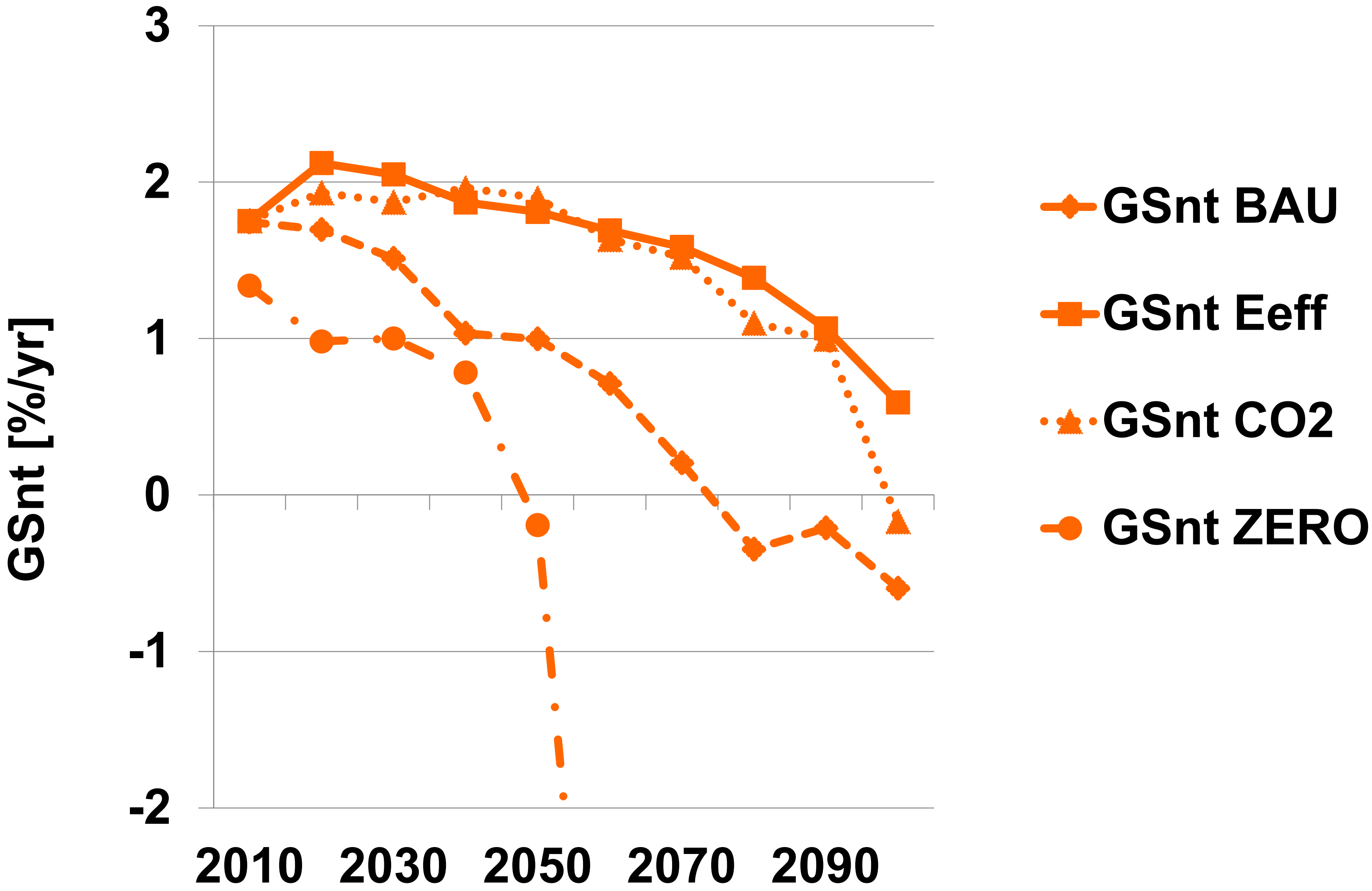
SD indicators
- Genuine Savings, Inclusive Wealth = non declining wealth (consumption, utility) in capital based approach

Model type	climate-economy IAM (Integrated Assessment Model)	bottom-up technology type Couple several systems together	Lifecycle impact assessment (LCIA)	Ours
Representative model name	DICE/RICE, PAGE, FUND	MARKAL, MESSAGE	Extern E, LIME	our original, unique
Model framework	Welfare maximization	Cost minimization	Dose-Response, economic valuation	Welfare maximization, interlinked bottom-up technology and LCIA
Damage assessment	aggregated, algebraic damage function	Most exclude damage functions	sector base impact models, choice experiments	LCIA
Feedback to economy	Yes	No	No	Yes
Natural resources	None	Various	Various	various

【results】 GS and breakdowns in the balance growth



Climate Policy scenario analysis



Conclusion

- We claim Genuine Savings are an effective indicator of the overall impact of policy options under climate change
- The forward looking nature of GS makes it impossible to produce a match for the theoretical concept…
- …But even our approximate method based on current mechanisms gives consistent results
- Using GS in IAM is a useful complement to using GS for the diagnosis of past and current performance