Feedbacks and Time Scale Interactions in Climate Change

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Introduction

- Climate change may modify the BAU emission scenario. Assessing this effect is one of the challenges of integrated assessment.
- The aim of this work is to assess and characterize this effect using simple model coupling.
- Two approaches:
  - An evaluation of the long characteristic times of the coupled climate-economy system, through a complete dynamic feedback analysis
  - An identification and quantification of the short-term interactions, with a simple disequilibrium economic model

First part: Assessment of the long characteristic times of the climate-economy feedback

Simple Macroeconomic model

- A classical Solow-Swan long-term growth model.
- Cobb-Douglas 2-factor production function: Labor (L) and Productive capital (K):

$$Y = \gamma \cdot L^{\lambda} \cdot K^{\mu} \cdot X$$
$$\frac{\partial K}{\partial t} = \alpha \cdot Y - \frac{1}{\tau_d} \cdot K$$

- Simulation model, with a fixed investment ratio (20%);
- It accounts for exogenous technical progress (impacting productivity).

Climate and Impact Module

Transient climate change impacts and endogenous adaptation process ("adaptive temperature", T_{ada}).

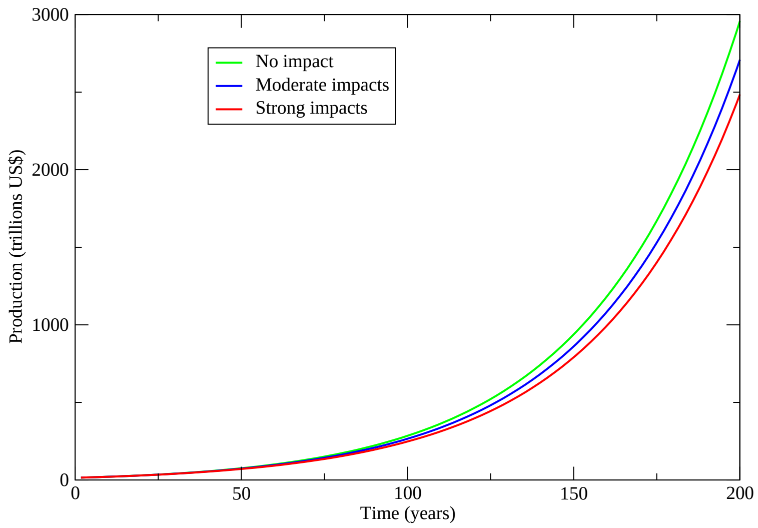
$$\frac{\partial T_{ada}}{\partial t} = \frac{1}{\tau_{ada}}(T_s - T_{ada})$$

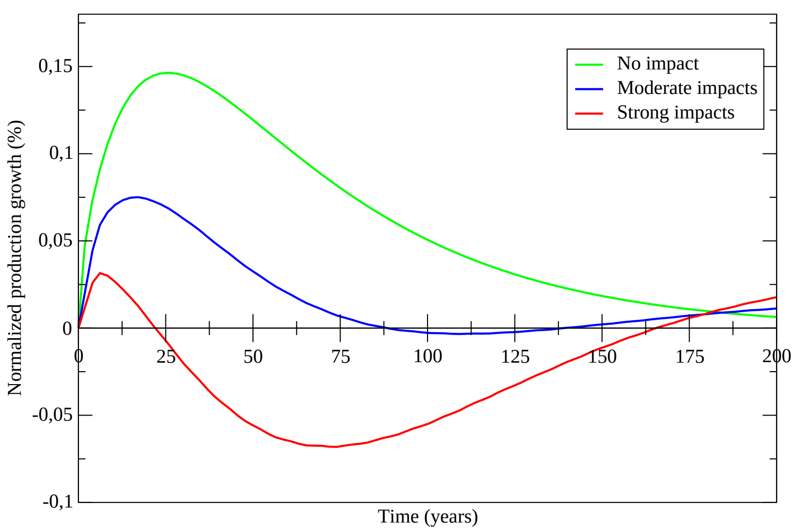
When T_{ada} and T_s differ, the socio-economic system is not adapted and it faces impacts:

- (i) through productivity losses:
- (ii) through a shortening of the life-time of productive capital:

Impacts depends on a race between climate change and adaptation.

Model Simulations: production for 3 hypothesis on impact level





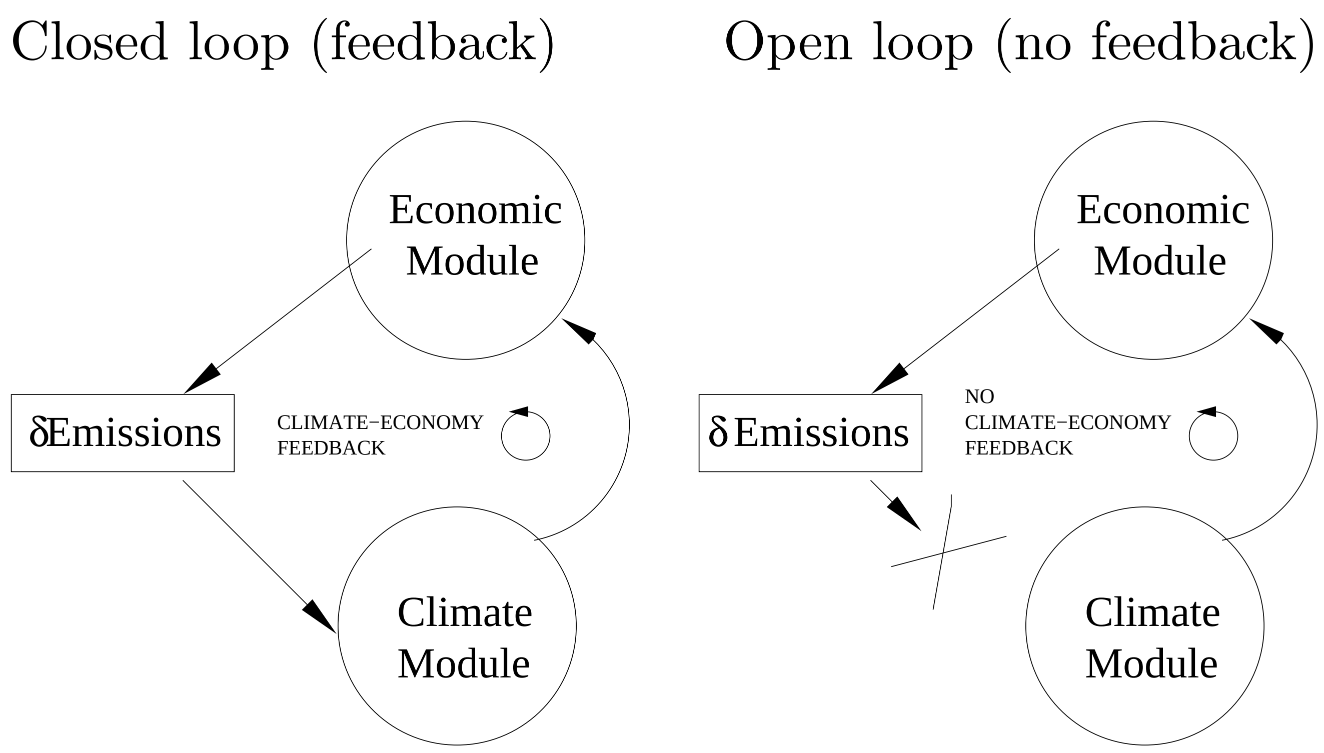


Figure 1: Scheme of the climate-economy feedback (left); and illustration of the open-loop model (right).

Feedback function:

Solving the Linear Tangent System gives:

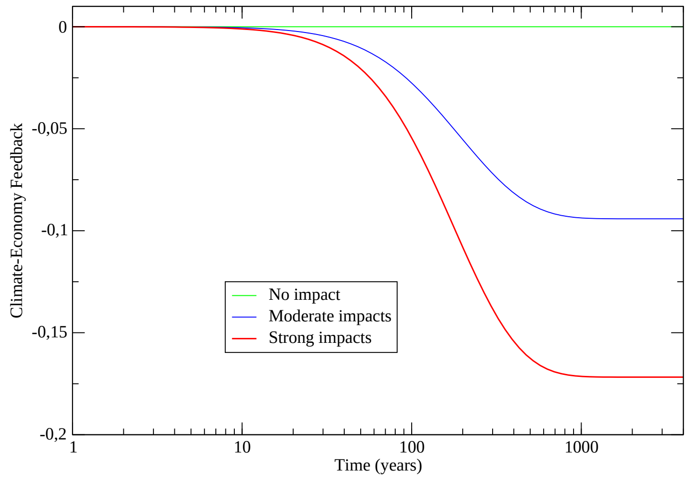
$$\mathring{\delta}\varphi_1(t) = \mathcal{B}^{-1}\left[\frac{1}{1-g_1(\tau)}\right] * \frac{d}{dt}\mathring{\delta}\varphi_{1\,ins}(t)$$

The Feedback function is defined by:

$$\mathring{\delta}F^R_{\varphi_1}(t) = \left(\mathcal{B}^{-1}\left[\frac{1}{1-g_1(\tau)}\right] - 1\right)$$

Interpretation :

If a perturbation is applied, which would have lead in the open loop model to a unit step in φ_1, then this perturbation lead, in the closed loop model, to the reponse $(1 + F^R_{\varphi_1}(t))$.



- An effort on emissions have its first consequences after 20 years
- The static gain is -10% $\Longleftrightarrow$ a 1% GWP growth will only represent a 0.9% growth because of the additional climate change induced.
- A long characteristic time of 80 years $\Rightarrow$ a *fair* cost-benefit analysis should consider more than one century (stock effects).

Second part: Short-term shocks in climate change

Preliminary work...

Limitations of long-term growth models

Long-term growth models and general equilibrium models are based on static representations of the exchanges:

- Parameters have to change slowly with respect to the time needed by price and wage to reach their steady states
- Any disequilibrium is supposed to be transient and to last a short period of time with respect to the time step of the model.
- Averaging the short-term perturbations over the time step of the model is supposed not to change the long-term behavior...

But the influence of climate upon economy is likely to involve mainly short-term disequilibrium processes (e.g. extreme events, thresholds...)

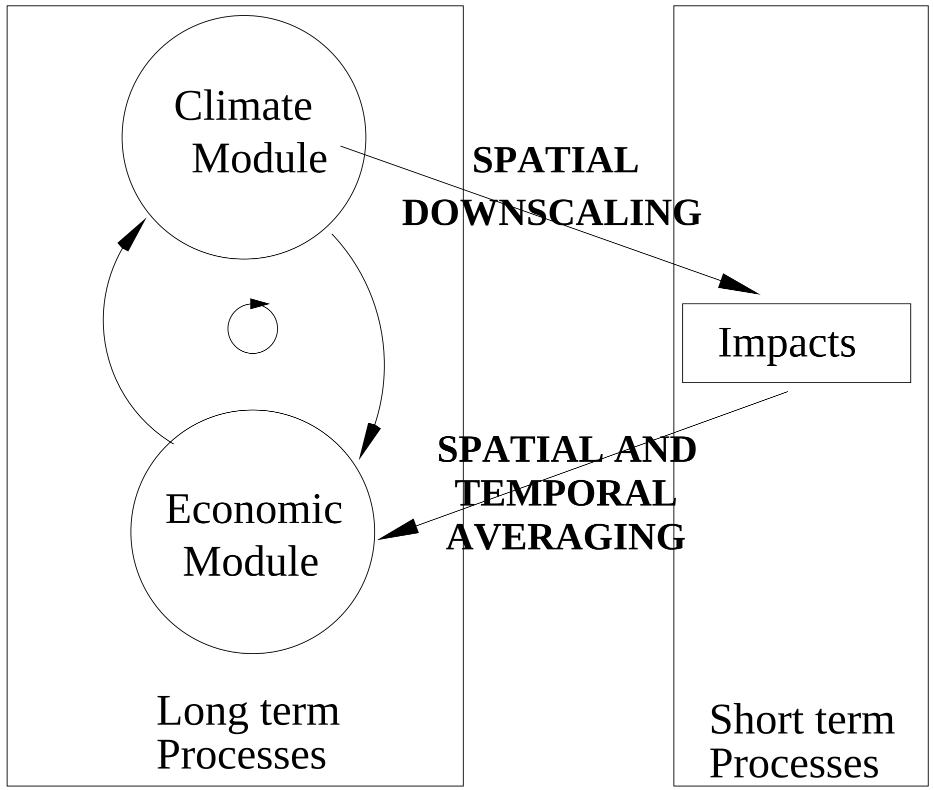


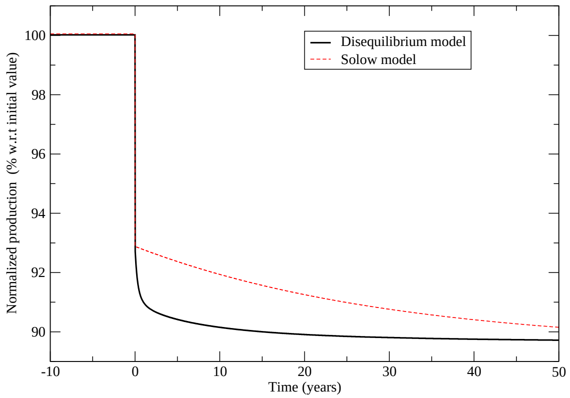
Figure 2: Scheme of the climate-economy feedback in IAM

Is it possible to feed economic models with averaged data ?

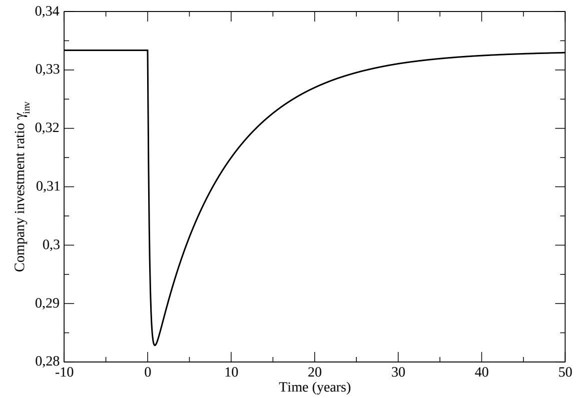
How can we do the averaging ?

Limitation of econometric short-term models

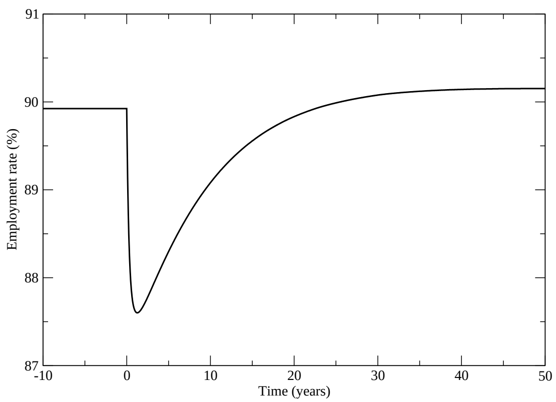
- We need models able to take into account short-term shocks (e.g. short-term econometric forecasting models, but these models are unable to carry out simulation over decades...)
- We modify the Solow model to take into account disequilibrium, even in a rough manner.
- Example: $\frac{\partial w}{\partial t} = \frac{w}{\tau_w} \cdot \frac{\hat{u}-u}{\hat{u}}$ and $\frac{\partial p}{\partial t} = \frac{p}{\tau_p} \cdot \frac{G}{Y}$
- Depending on the investment modeling and parameters: convergence to a stable equilibrium, limit cycle or chaotic behavior.



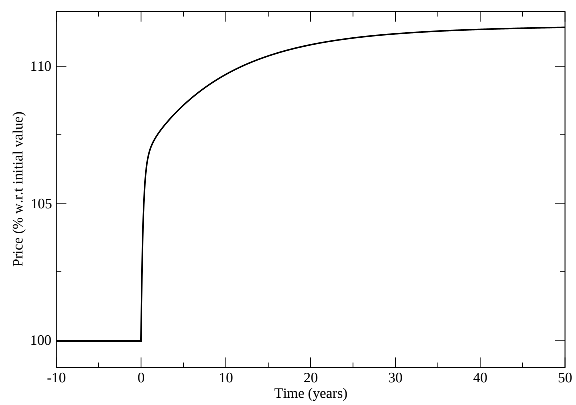
(a) Production



(b) Company investment ratio γ_{inv}



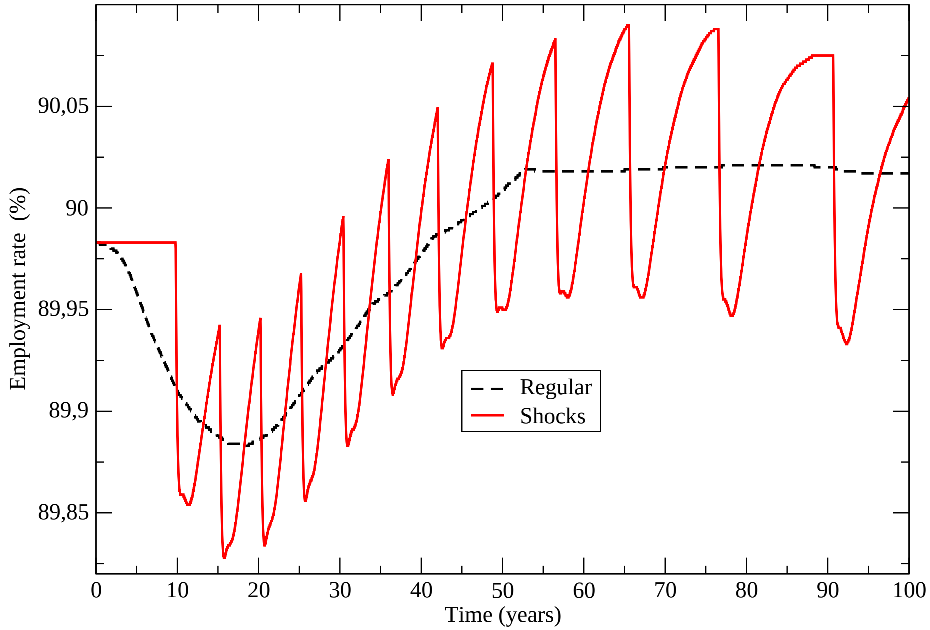
(c) Employment rate



(d) Price

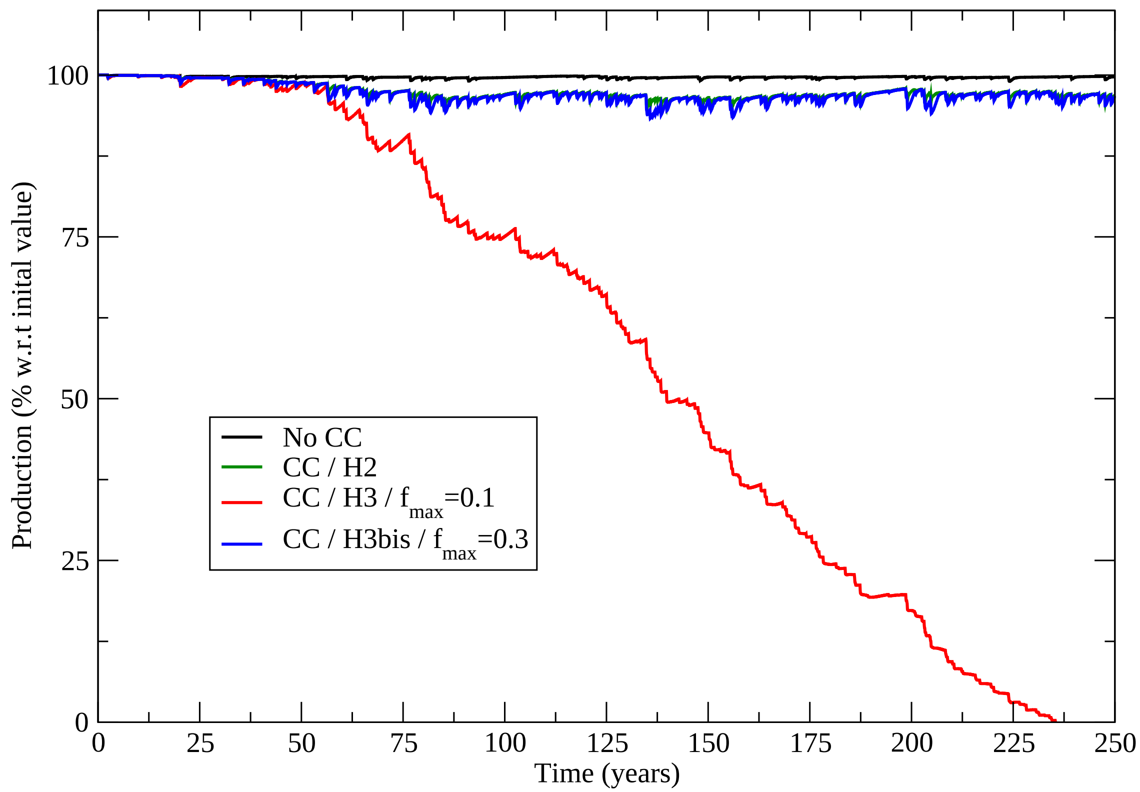
Figure 3: Model response to a shock in productivity.

Unemployment in case of regular or irregular climate change impacts



The impact on welfare would be completely different in case of a series of shocks. Investment response would also be strongly different, probably leading to different growth pathways.

Production change due to extreme events in a climate change context



Conclusions and Perspectives

- Climate change will not be a continuous and regular process
- Assessing its damages necessitates to take into account the short-term shocks that it will induce.
- What if the economic models able to provide GHG emissions scenarios are not able to capture climate change impacts?
- Economic models used in scenario development and damage assessment are not able to capture these processes: further work on economic short-term/long-term interactions is needed in order to produce confident results.

  e.g. in the model an additional risk premium of 2% on investment leads to a 6% additional unemployment
- Tools able to characterize dynamic processes and to analyse scale interactions are necessary.