THE GEMMES RESEARCH PROGRAM

Venice, Spring 2018

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Outlines

GEMMES

Overview of the research project

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Overview of the research project

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GEneral Monetary

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Overview of the research project

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GEneral Monetary Multisectoral

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GEneral Monetary Multisectoral Macrodynamics

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Overview of the research project

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GEneral Monetary Multisectoral Macrodynamics for the Ecological Shifts

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GEneral Monetary Multisectoral Macrodynamics for the Ecological Shifts

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Overview of the research project

Goodwin

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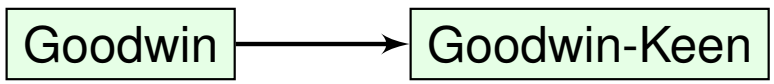
Overview of the research project



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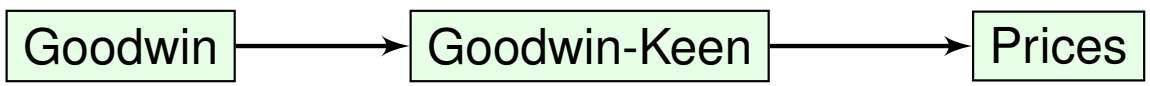

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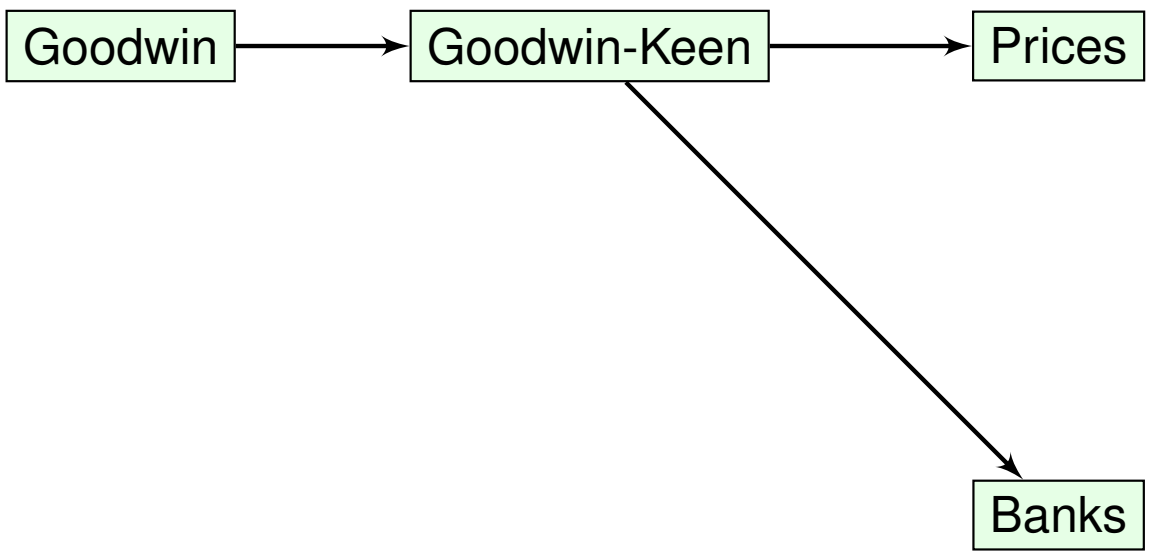

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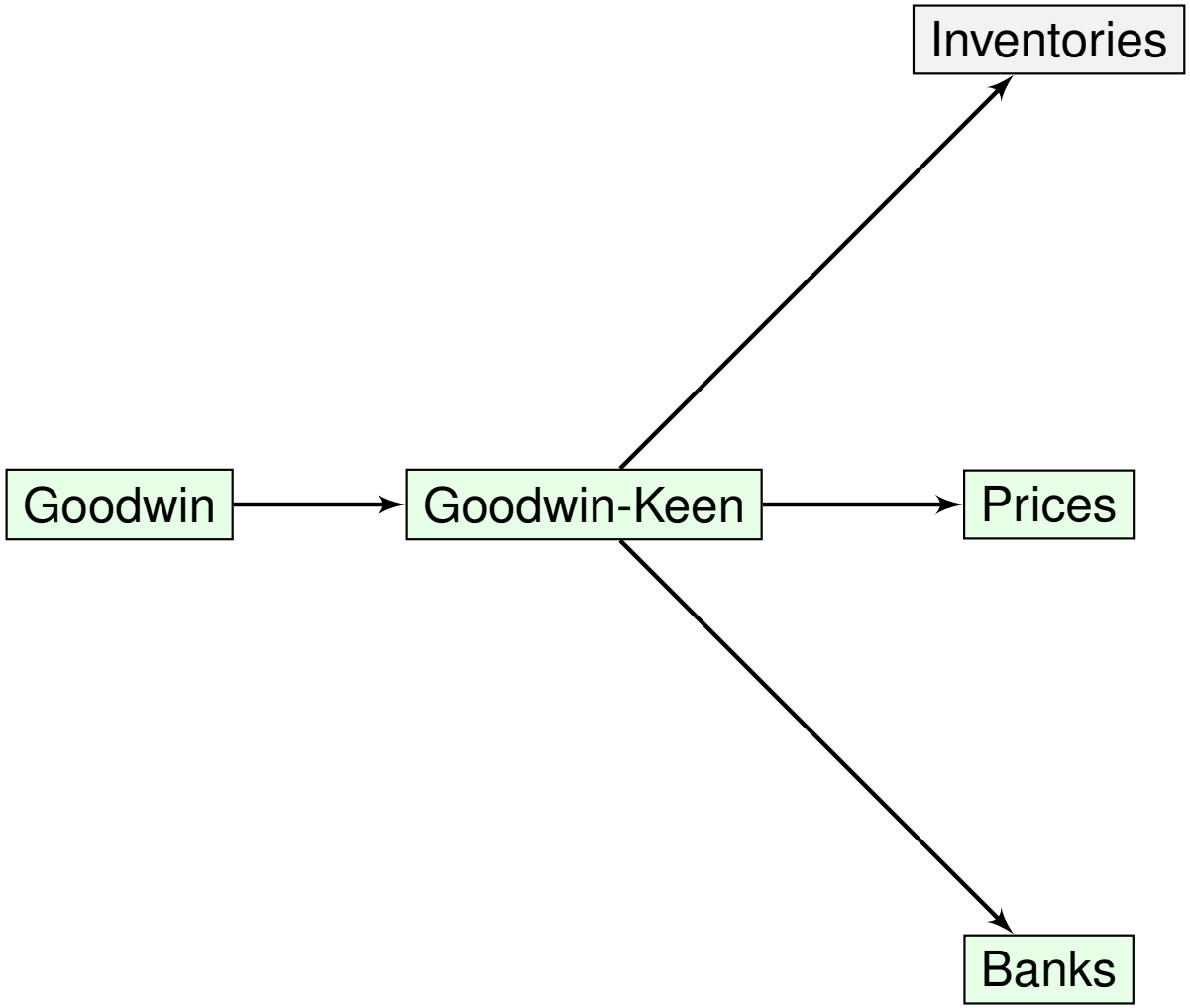

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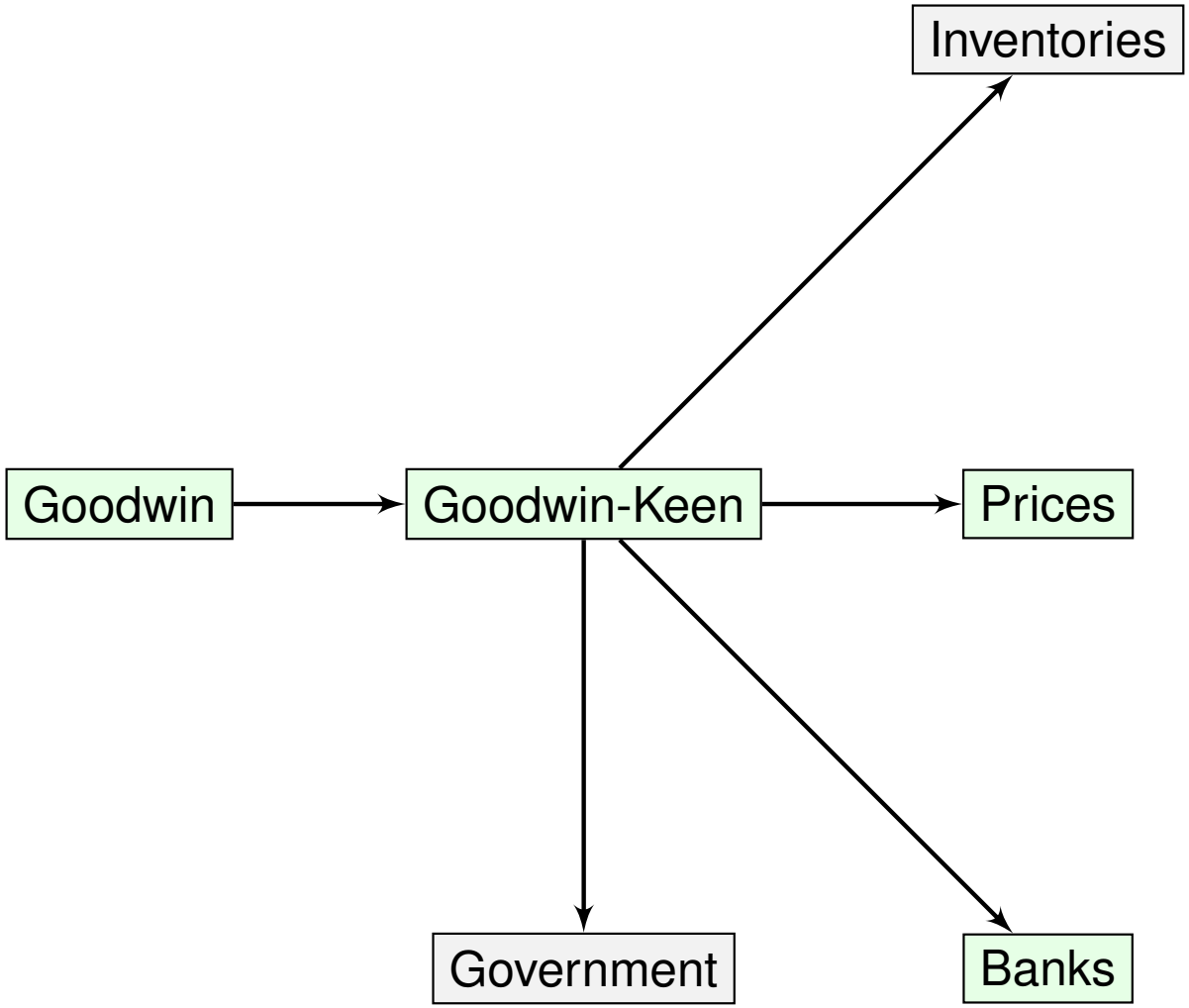

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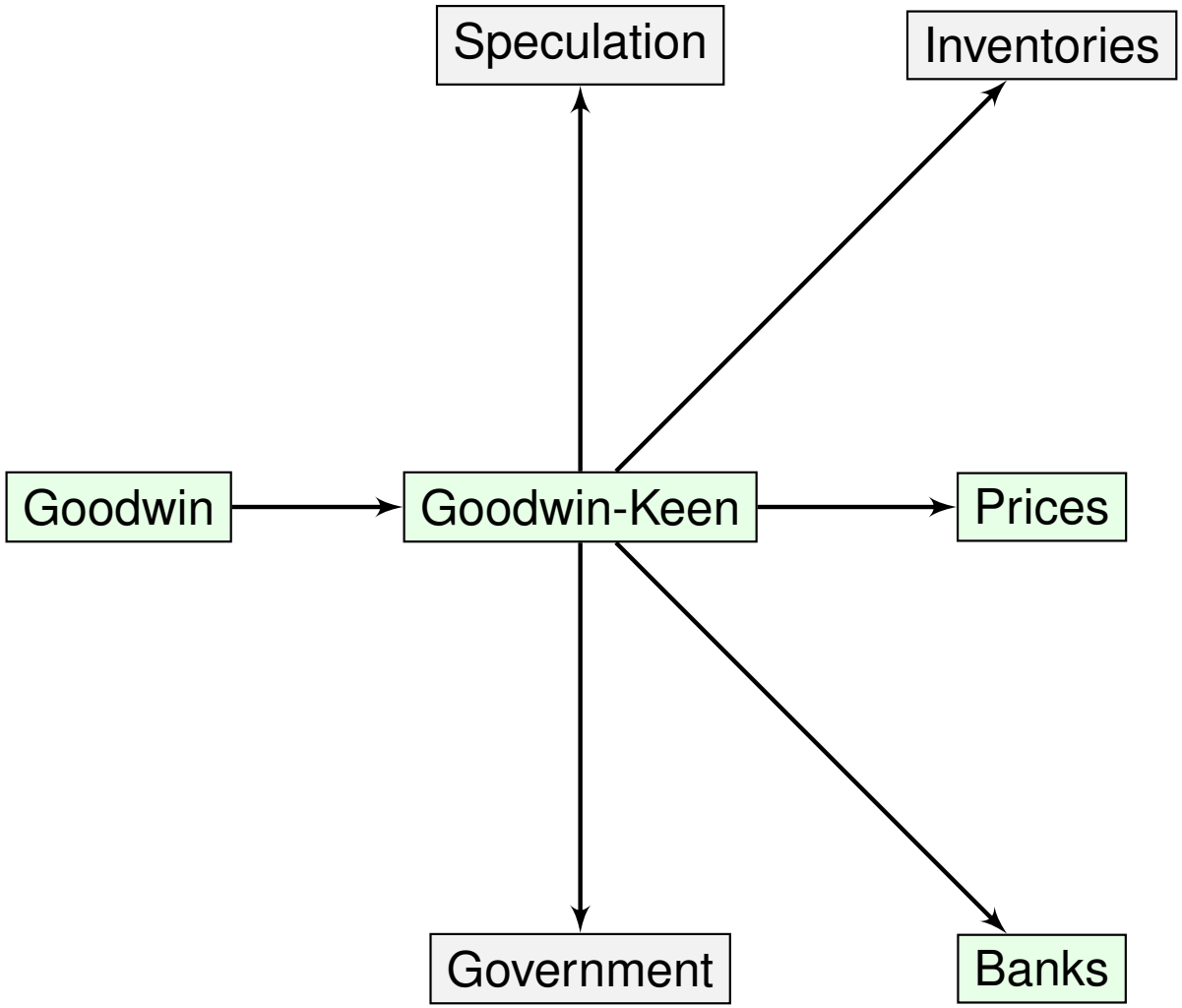

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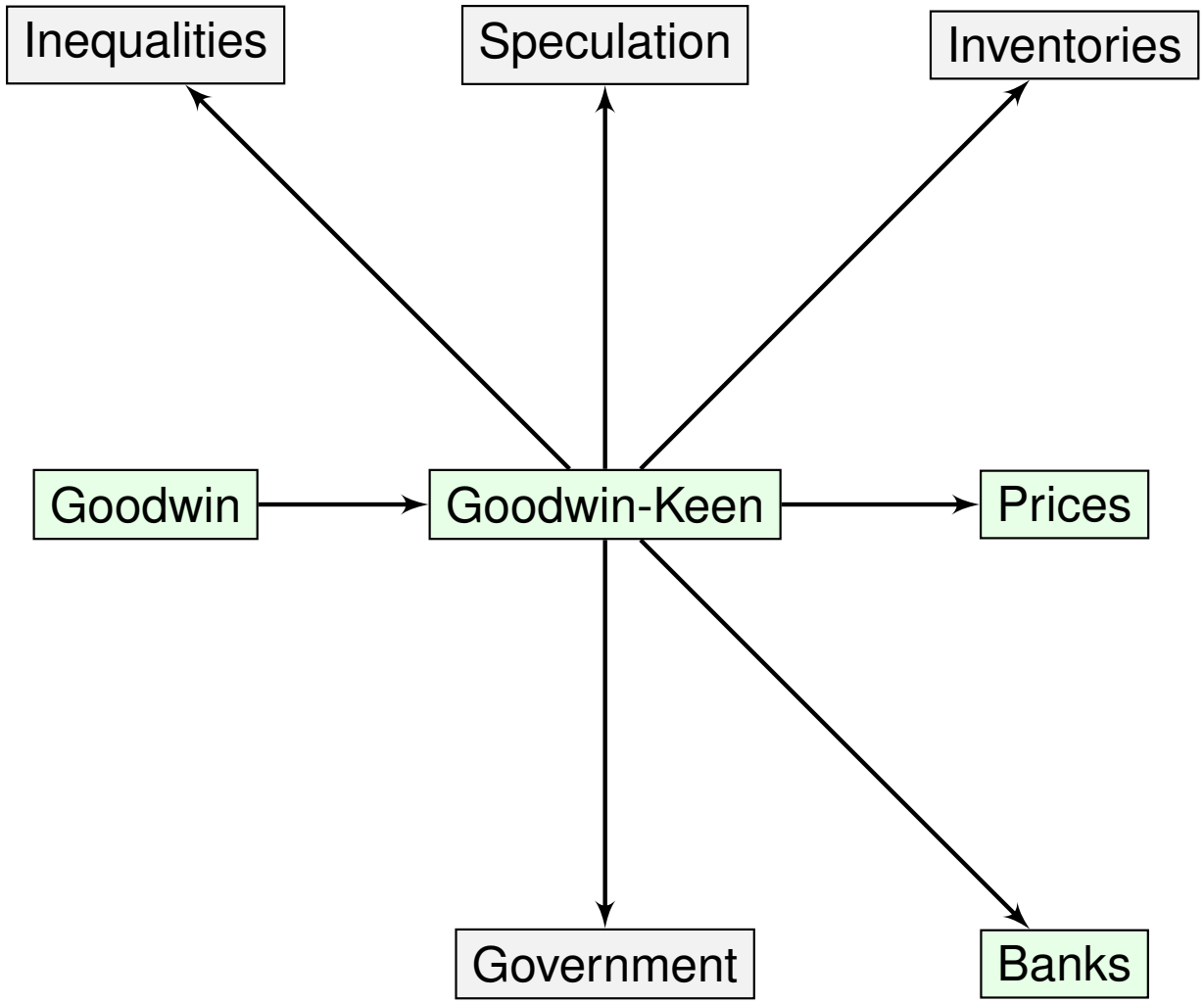

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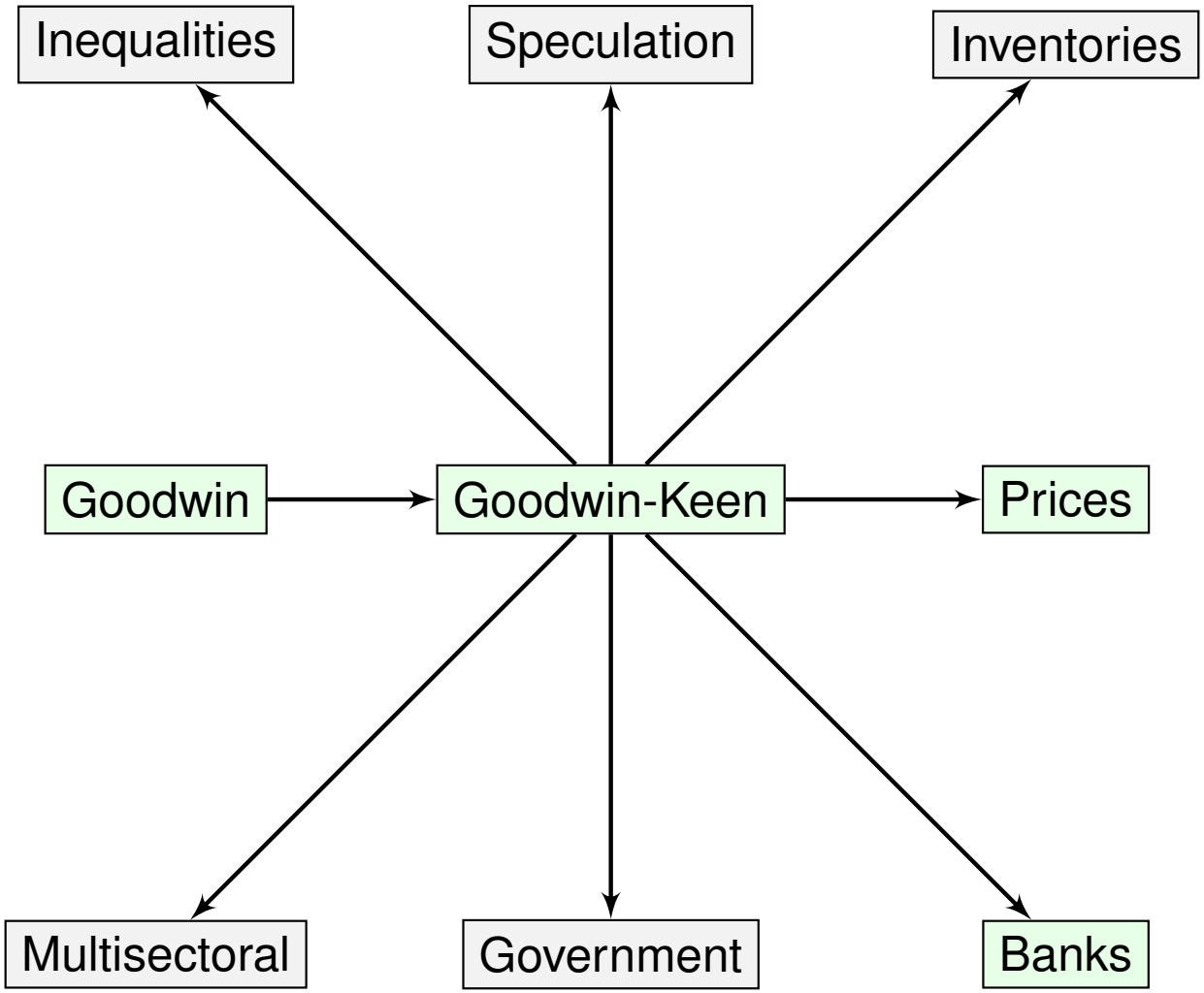

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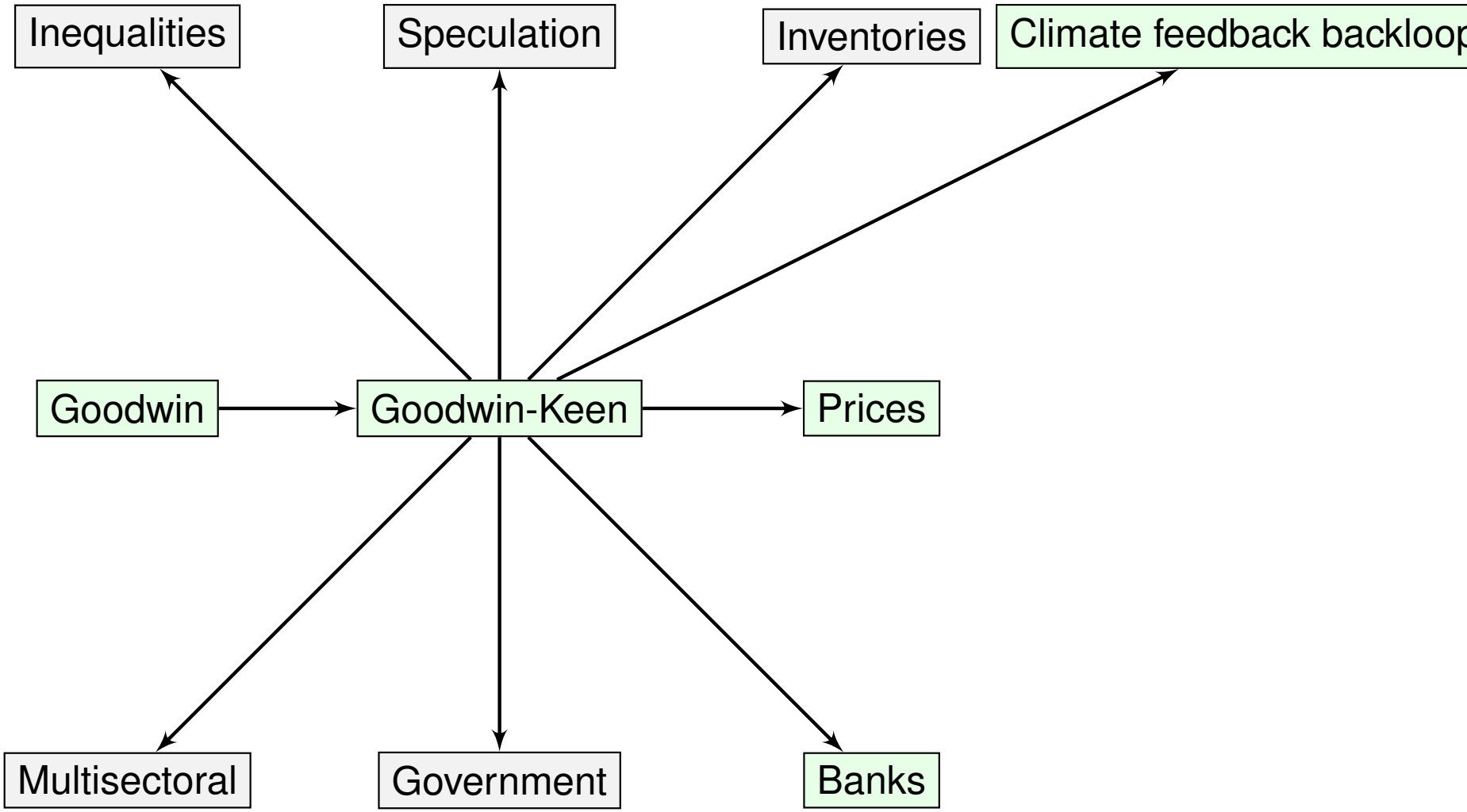

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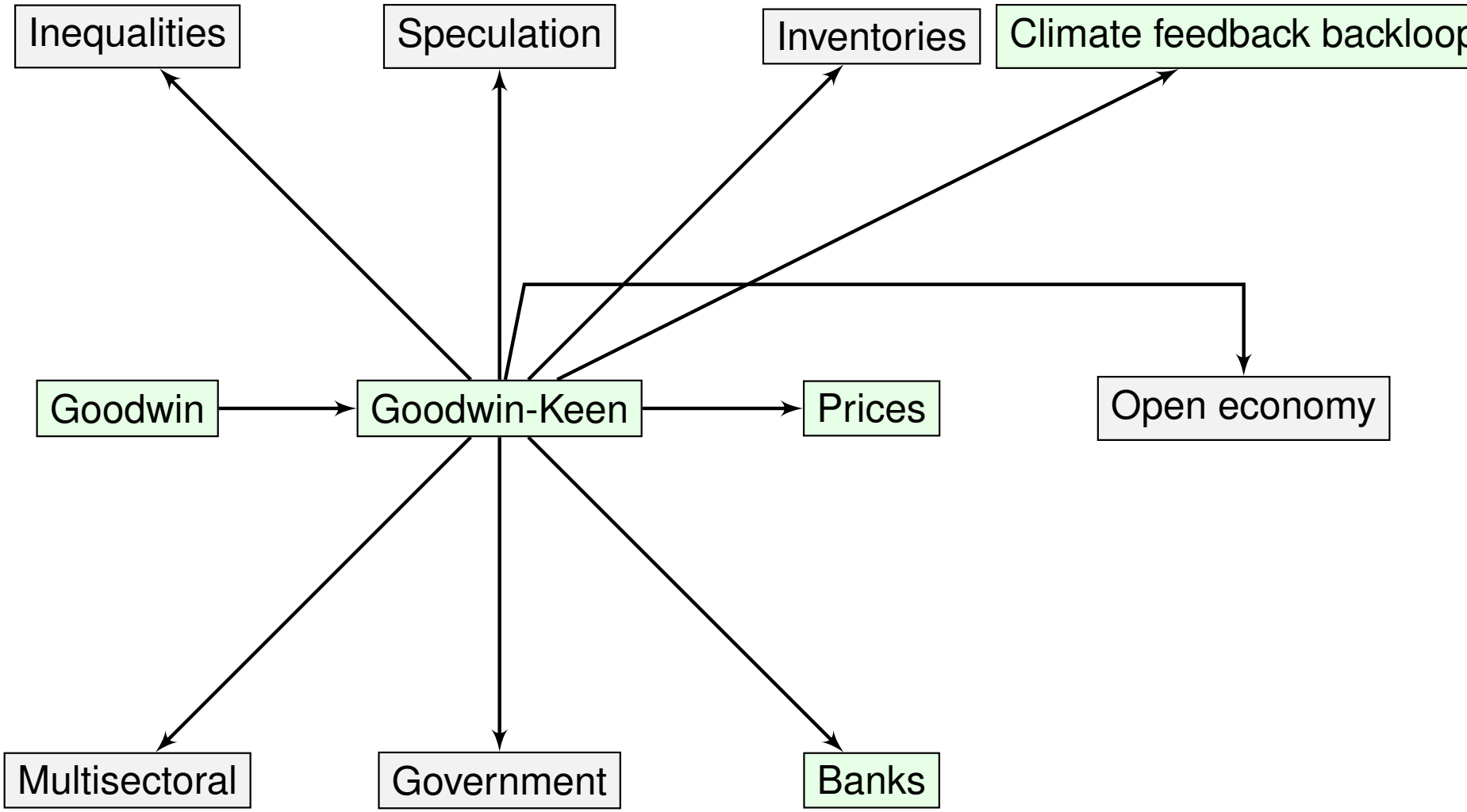

Outlines

The Keen (1995) Model

Private debt matters

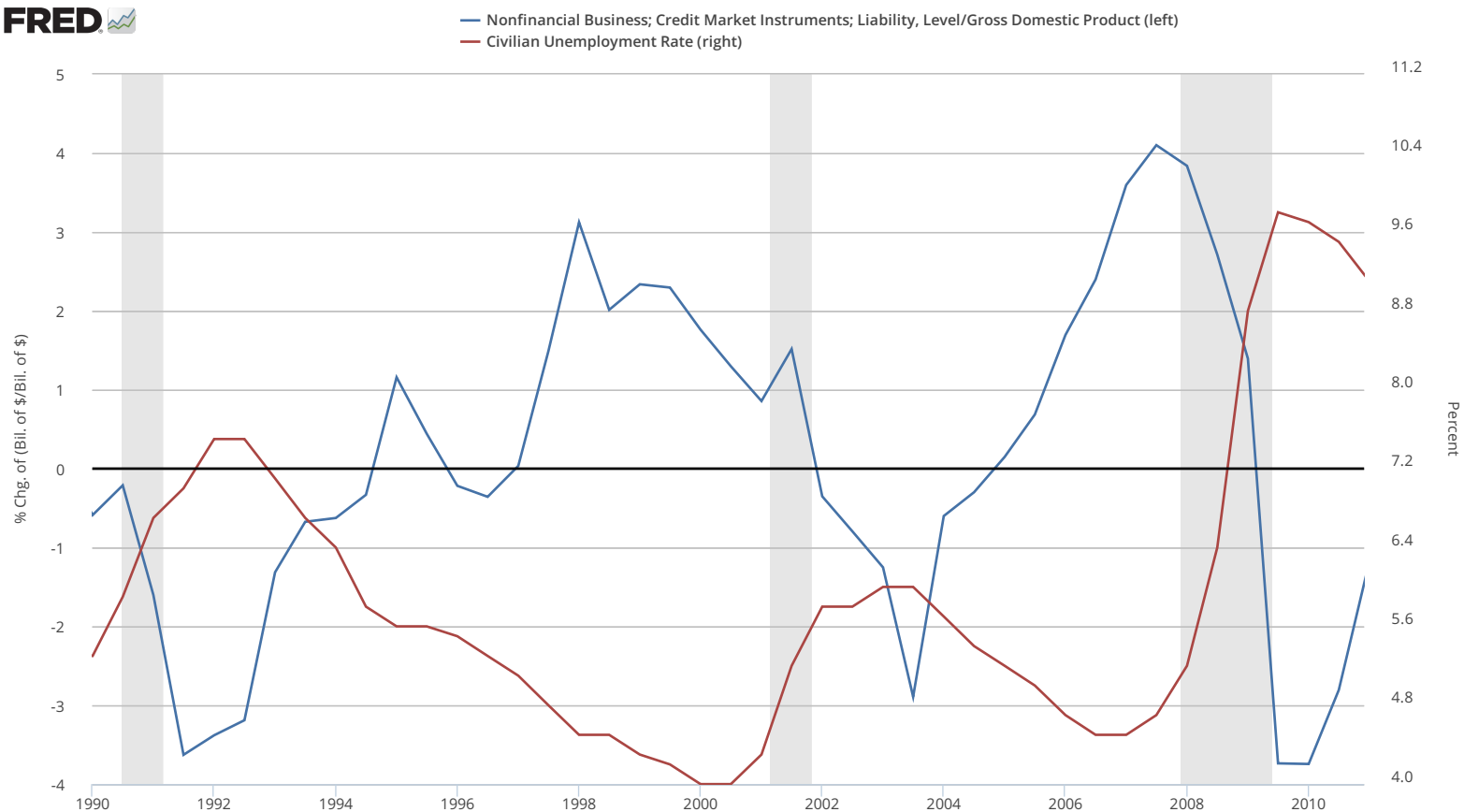

Figure: Change in private debt and employment rate in the United States – Period 1990-2010.

The Keen (1995) Model

Private debt matters

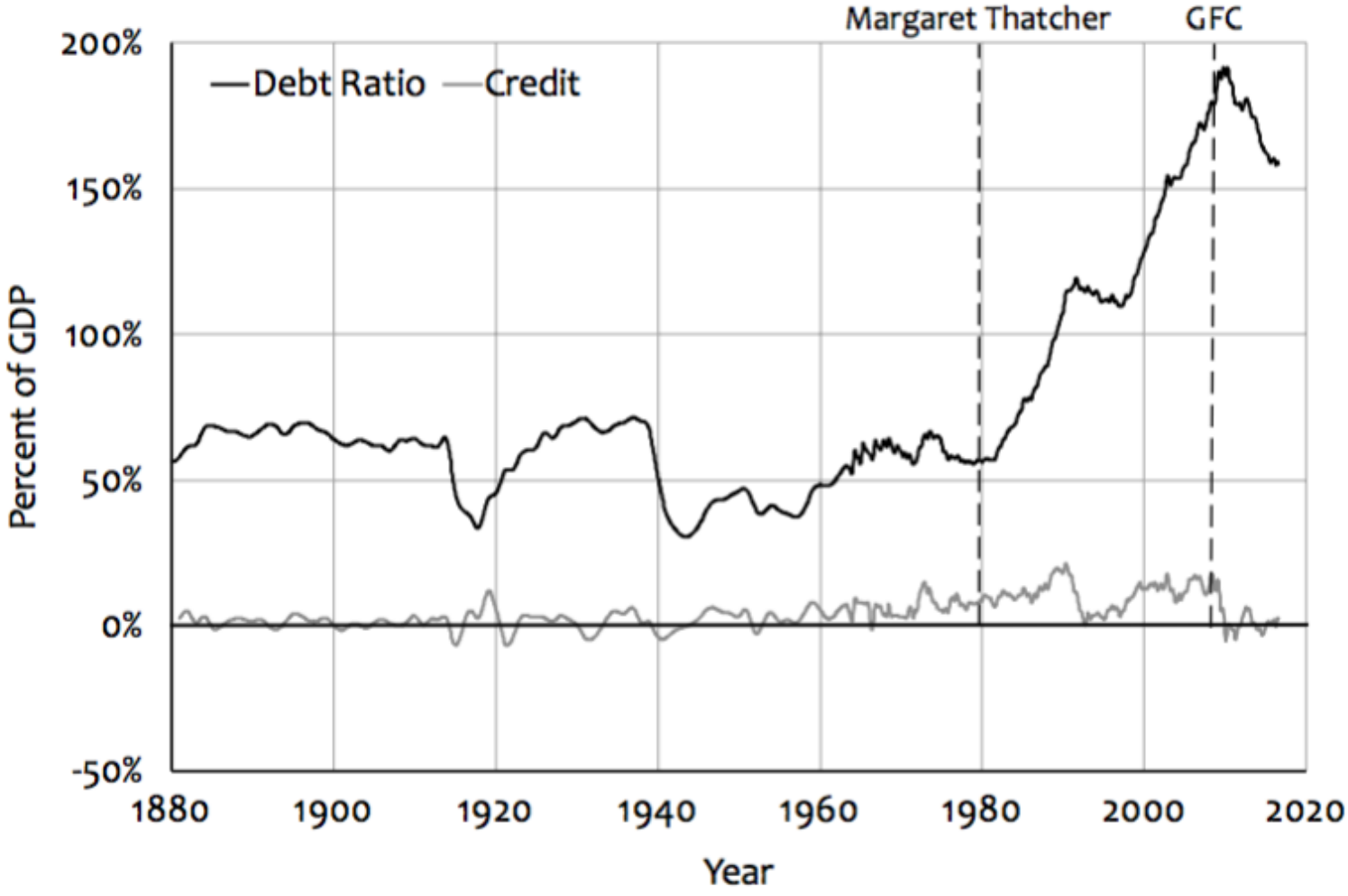

Figure 16. UK private debt since 1880

The Keen (1995) Model

Private debt matters

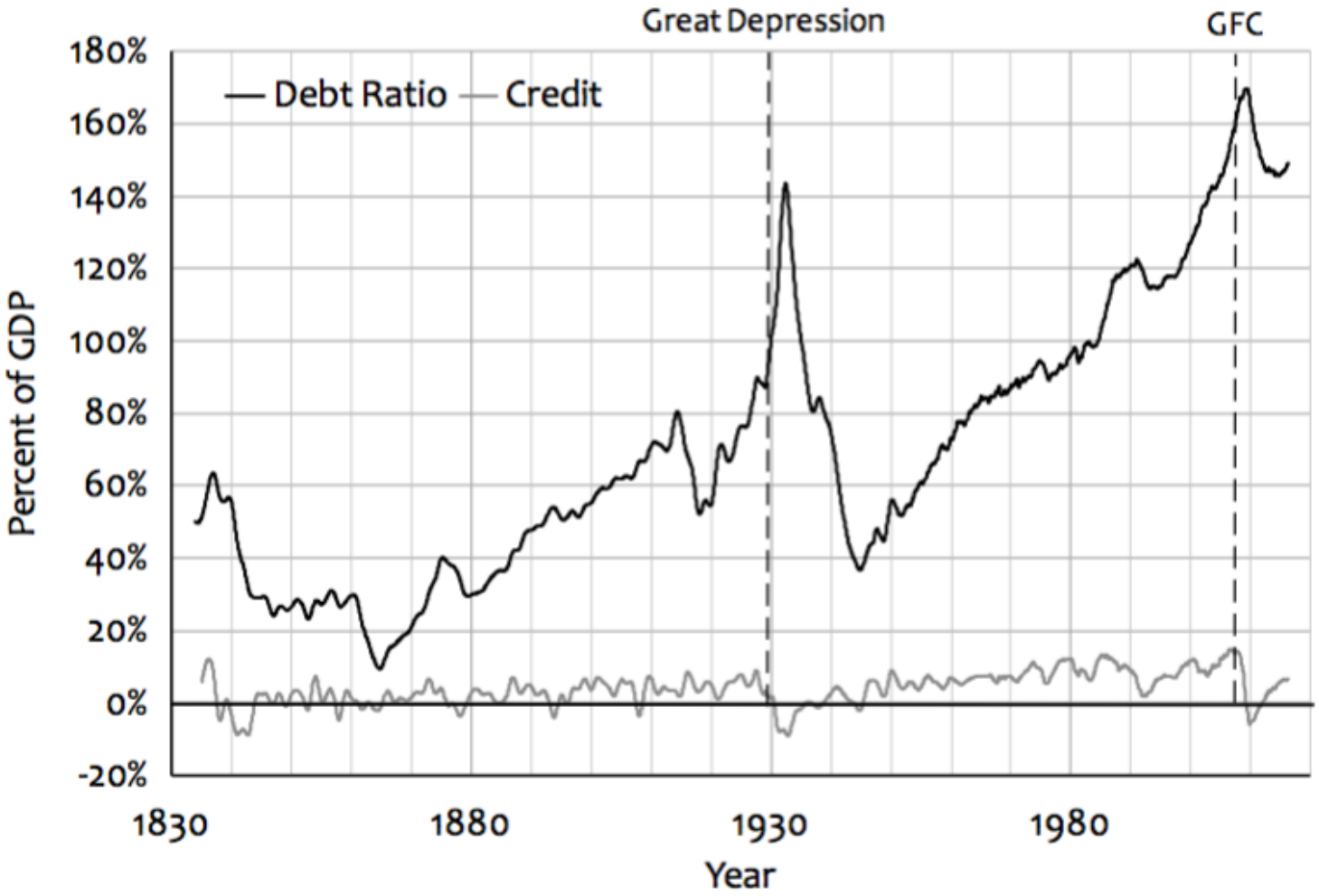

Figure 19. US private debt and credit from 1834

The Keen (1995) Model

Overview of the model

Since the financial crisis of 2007-2009, the ideas of Hyman Minsky around the intrinsic instability of a monetary market economy have experienced a significant revival.

1. Goodwin (1967): Lotka-Volterra logic of the wage share and the employment rate.

The Keen (1995) Model

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1. Goodwin (1967): Lotka-Volterra logic of the wage share and the employment rate.
2. Keen (1995): a Minsky moment can occur.
3. Investment financed by endogenous money creation (discussion with Nguyen-Huu-Pottier (2017)).

The Keen (1995) Model

The model

λ: the employment rate.

$$\lambda := \frac{L}{N}.$$

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w: the wage per worker, $W = wL$: the total wage, ω: the wage share ; Y: the production.

$$\omega = \frac{W}{Y} = \frac{wL}{aL} = \frac{w}{a}$$

The Keen (1995) Model

The model

K: the stock of capital.

$$\dot{K} = I - \delta K.$$

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The Leontief production function

$$\begin{aligned} Y &= \min\left(\frac{K}{\nu}, aL\right) \\ &= \frac{K}{\nu} = aL. \end{aligned}$$

The Keen (1995) Model

The model

D: the aggregate debt.

$$\dot{D} = I - \Pi.$$

with $\Pi := Y - W - rD$: the real profit of the firm, and r: the interest rate.
π: the profit-to-production ratio.

$$\pi = \frac{\Pi}{Y}.$$

The Keen (1995) Model

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d: the debt-production ratio.

$$d = \frac{D}{Y}.$$

The Keen (1995) Model

Aggregate behaviours

- The Short-term Phillips Curve (Mankiw, 2010).

$$\frac{\dot{w}}{w} = \phi(\lambda).$$

The Keen (1995) Model

Aggregate behaviours

- The Short-term Phillips Curve (Mankiw, 2010).

$$\frac{\dot{w}}{w} = \phi(\lambda).$$

- The Investment Function : it evolves positively with the profit share.

$$\frac{I}{Y} = \kappa\left(\pi\right).$$

The Keen (1995) Model

The three-dimensional system

One can retrieve the following set of equations:

$$
\begin{aligned}
\dot{\omega} &= \omega\left[\phi(\lambda) - \alpha\right] \\
\dot{\lambda} &= \lambda\left[\frac{\kappa(\pi)}{\nu} - \delta - \alpha - \beta\right] \\
\dot{d} &= d\left[r - \frac{\kappa(\pi)}{\nu} + \delta\right] + \kappa(\pi) - (1 - \omega)
\end{aligned}
$$

The Keen (1995) Model

Aggregate behaviours

- Phenomenological approach: $\phi(.)$ and $\kappa(.)$ are empirically estimated.
- Sonnenschein-Mantel-Debreu (1975): emergence is possible.
- Agent-based model.

The Keen (1995) Model

Equilibria analysis

Two economically meaningful long run equilibria:

- A good equilibrium locally stable:
  - Positive employment rate and wage share, finite level of debt.
  - Growth rate in line with the Solow or Harrod-Domar models.[1]

[1] The sum of the technical progress growth and the population growth.

The Keen (1995) Model

Equilibria analysis

Two economically meaningful long run equilibria:

- A good equilibrium locally stable:
  - Positive employment rate and wage share, finite level of debt.
  - Growth rate in line with the Solow or Harrod-Domar models.[1]
- A bad equilibrium locally stable:
  - Employment rate and wage share collapsing, infinite level of debt.
  - Situation of economic crisis.

[1] The sum of the technical progress growth and the population growth.

Outlines

Coping with the Collapse –

Physical processes overview

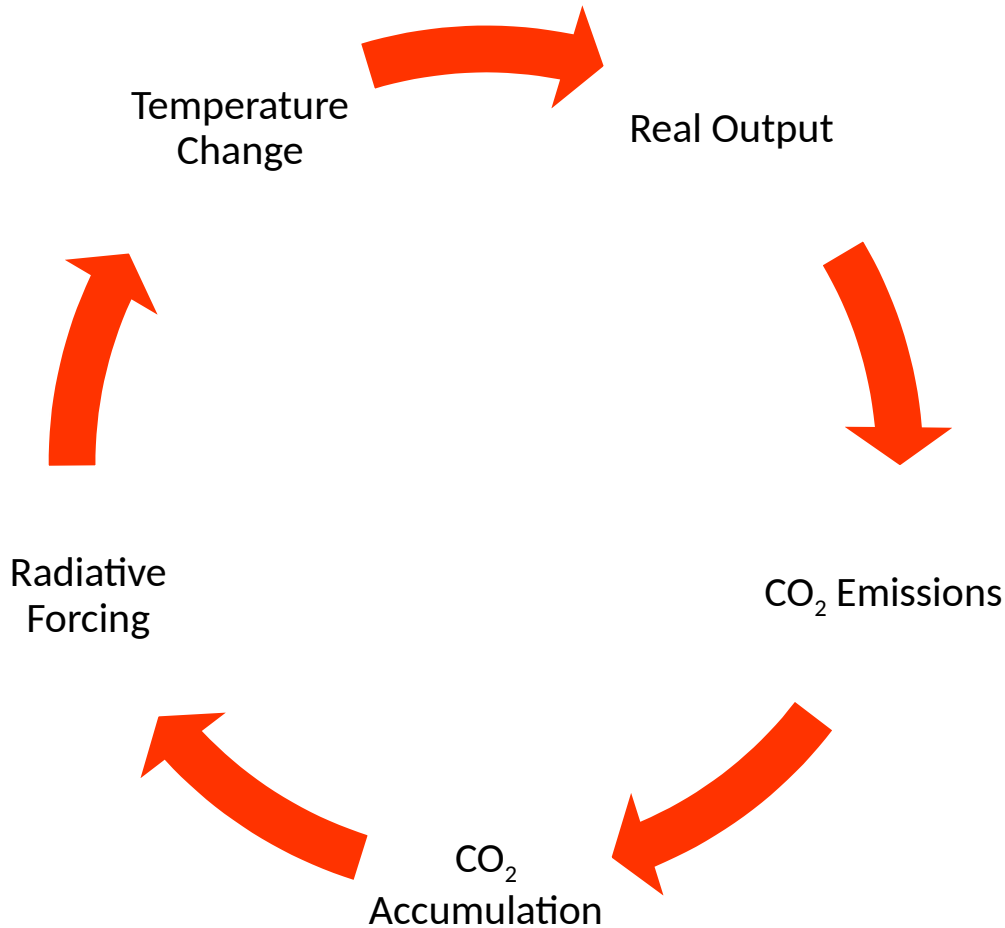

Figure: Climate-economy interactions diagram.

Coping with the Collapse –

Climate damage as a percentage of real GDP

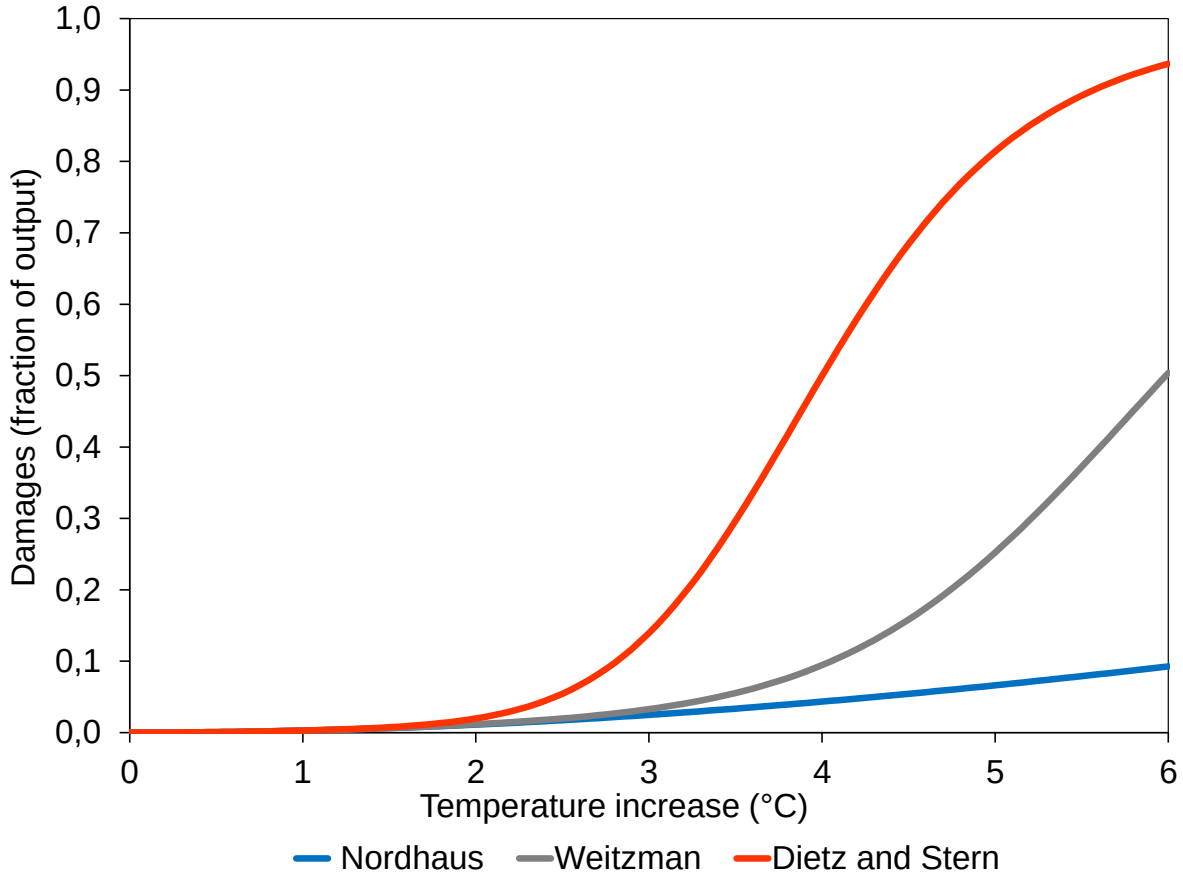

Figure: Shape of various damage functions.

Coping with the Collapse

Stock-flow consistency

	Households	Productive Sector		Banks	Sum
Balance Sheet					
Capital stock		pK			pK
Deposits	M^h	M^c		$-M$	
Loans		$-L_c$		L_c	
Equities	E	$-E^f$		$-E^b$	
Sum (net worth)	X^h	$X^f = 0$		$X^b = 0$	X
Transactions		current	capital		
Consumption	$-pC$	pC			
Investment		pI	$-pI$		
Acc. memo [GDP]		$[pY]$			
Wages	W	$-W$			
Capital depr.		$-(\delta + \mathbf{D}^{\mathrm{K}})pK$	$(\delta + \mathbf{D}^{\mathrm{K}})pK$		
Carbon taxes	pT_f	$-pT_f$			
Int. on loans		$-r_c L_c$		$r_c L_c$	
Bank's dividends	Π_b			$-\Pi_b$	
Productive sector's dividends	Π_d	$-\Pi_d$			
Int. on deposits	$r_M M^h$	$r_M M^c$		$-r_M M$	
Column sum (balance)	S^h	S^c	$-pI + (\delta + \mathbf{D}^{\mathrm{K}})pK$	S^b	
Flow of Funds					
Change in capital stock		$p\dot{K}$			$p\dot{K}$
Change in deposits	$\dot{M}^h$	$\dot{M}^c$		$-\dot{M}$	
Change in loans		$-\dot{L}_c$		$\dot{L}_c$	
Column sum (savings)	S^h	S^c		S^b	
Change in equities	$\dot{E}^f$	$-(S^c + p\dot{K})$			
Change in bank equity	$\dot{E}^b$			$-S^b$	
Change in net worth	$S^h + \dot{E}$	0		0	$p\dot{K}$

Coping with the Collapse –

Dynamics and behavioural relations

- Short term Phillips curve: $\frac{\dot{w}}{w} = \phi(\lambda)$
- Dynamic of prices (Grasselli *et al.*, 2014): $\frac{\dot{p}}{p} = \eta(mc - 1)$
- Investment behavior: $I = \kappa(\pi)$
- Population dynamics taken from the UN median scenario.

Coping with the Collapse

Key modeling highlights

Bridging climate and a global monetary economy

Coping with the Collapse

Key modeling highlights

Bridging climate and a global monetary economy

1. The macroeconomic core
   - Non-neutrality of money
   - Severe breakdowns do not appear as “black swan events”
   - Emissions, carbon price and abatement technology (Nordhaus, 2016)
   - Price dynamics under imperfect competition (Grasselli *et al.*, 2014)
   - Sigmoïd pattern of the global workforce (UN population scenarios, 2015)
   - Dividends payments

Coping with the Collapse

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2. The DICE climate feedback loop of Nordhaus (2016) refined with
   - More convex damage functions (Weitzman, 2011)
   - Allocation of environmental damages between output and capital (Dietz *et al.*, 2015)

Coping with the Collapse

Research questions

- Combine two sources of global instabilities, climate and finance, in a minimal dynamic framework to perform a prospective analysis.

  Can climate change drive the global economy in a deep recessionary state?

Coping with the Collapse

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- Combine two sources of global instabilities, climate and finance, in a minimal dynamic framework to perform a prospective analysis.

  Can climate change drive the global economy in a deep recessionary state?

- Provide guidance for the implementation of public policy objectives in order to ensure economic stability and perform the energy shift.

  Is a price signal sufficient to prevent such a situation?

Coping with the Collapse

Main findings

- In a business as usual scenario, climate change drives the global economy toward a situation of “economic collapse”.
- A price signal (carbon tax) provides indeed the right incentives to perform the energy shift and avoid most of climate damages.
- However, financial risks are not entirely precluded: in line with the Stern-Stiglitz report (2017), a green public intervention is required to tackle both instabilities.
- There seems to be a link between the distribution of income and the economic resilience towards climate change.

Coping with the Collapse –

Convergence toward a steady-state absent climate change impact

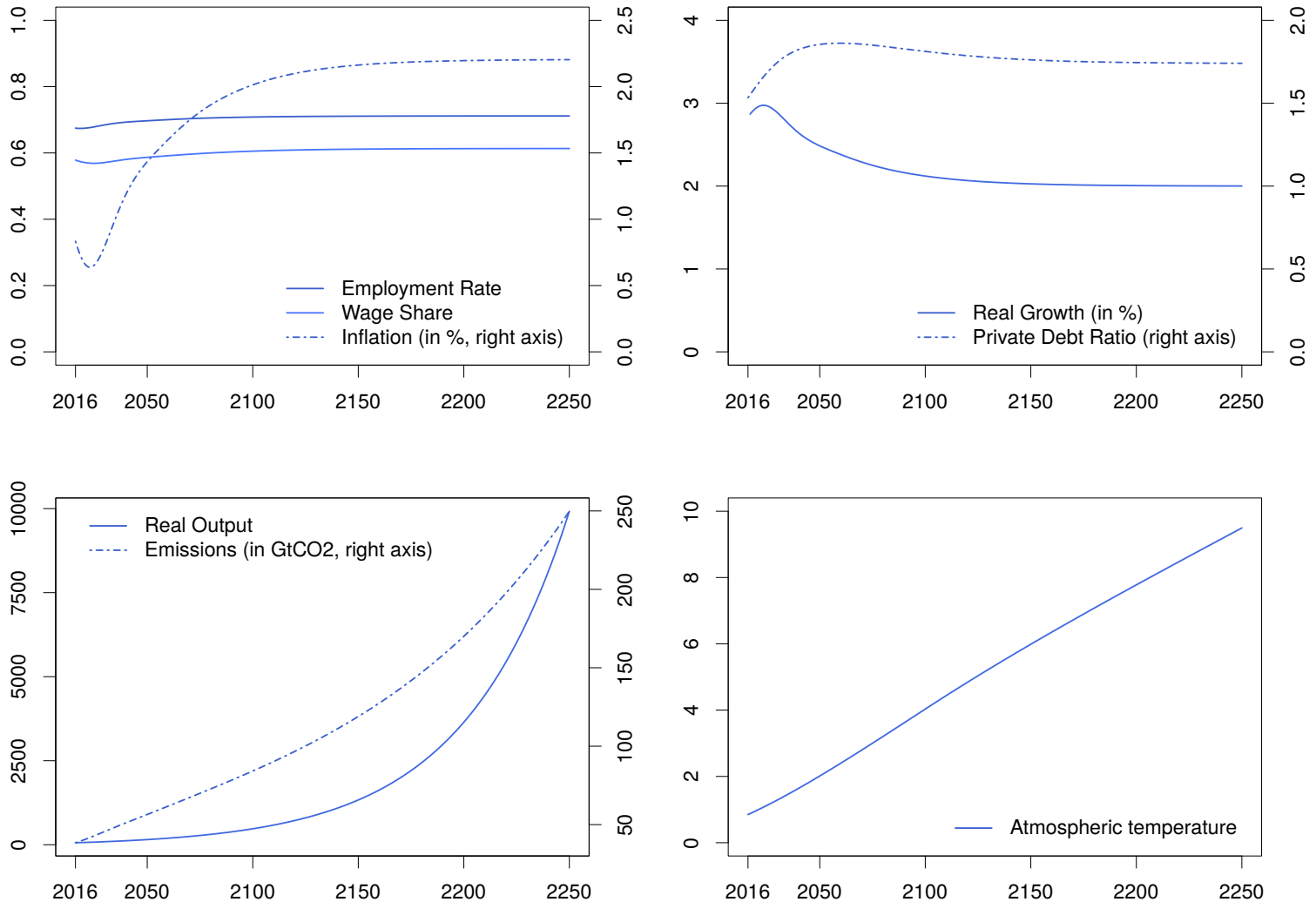


Figure: Trajectories of the main simulation variables.

Coping with the Collapse –

Impact of temperature change on the solovian steady-state

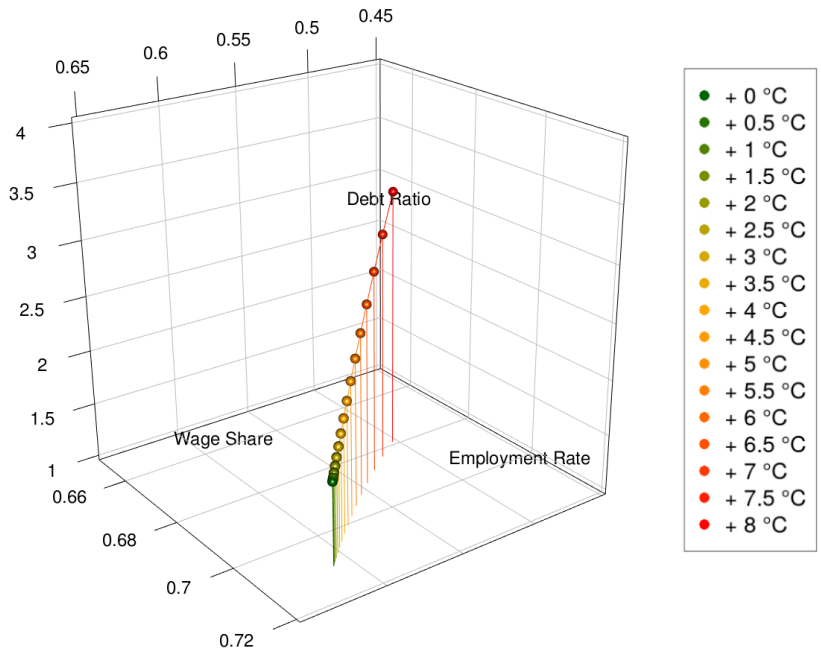


Figure: Type 1 scenario.

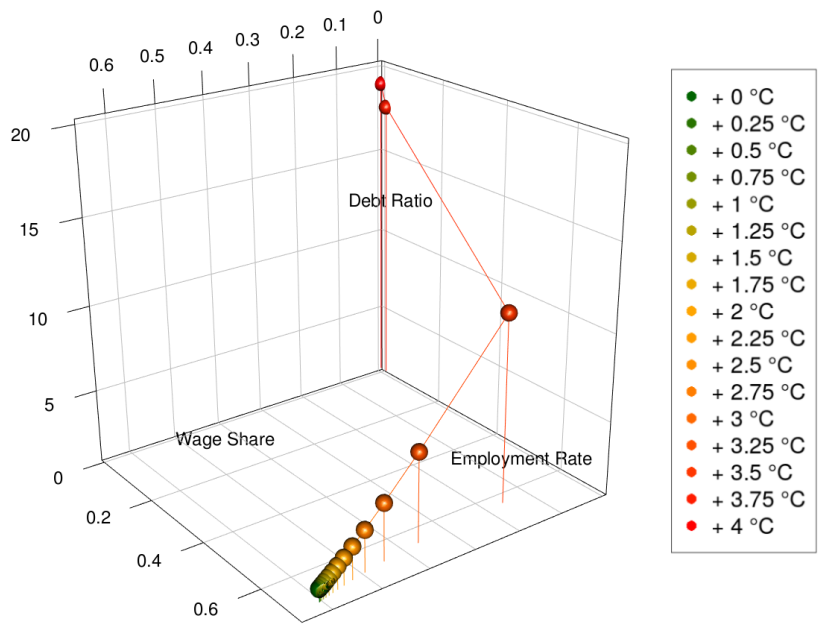


Figure: Type 3 scenario.

Coping with the Collapse –

The basin of attraction of the solovian steady-state

Figure: Baseline scenario.

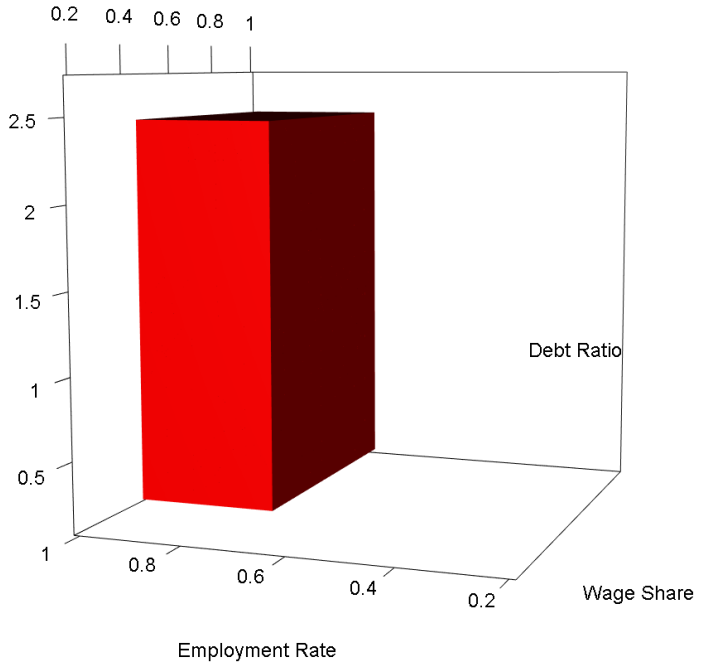


Figure: Type 1 scenario.

Coping with the Collapse –

A need for public involvement

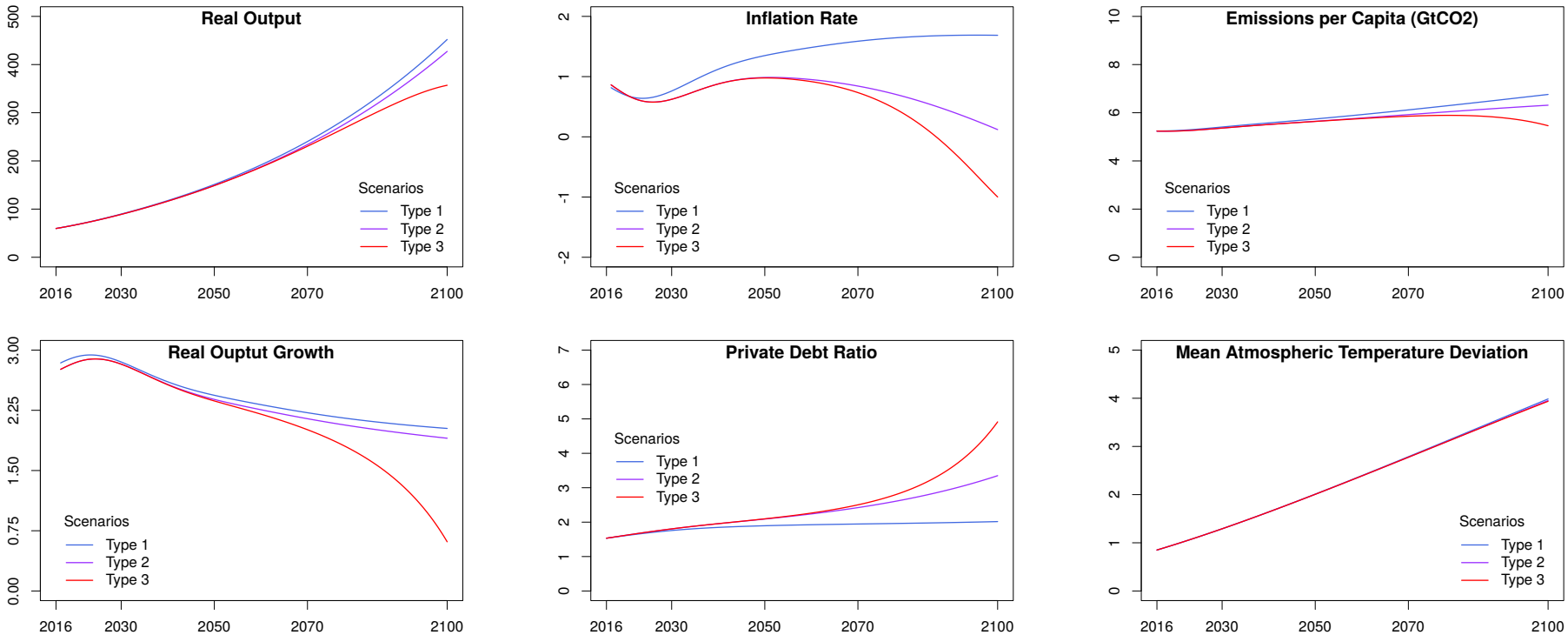


Figure: Trajectories of the main macroeconomic and climate variables.

Coping with the Collapse –

Which temperature targets can be reached?

- Nordhaus (2016) following a recalibration of the climate module of DICE:[2]

> *The study confirms past estimates of likely rapid climate change over the next century if there are not major climate-change policies. It suggests that it will be extremely difficult to achieve the 2° C target of international agreements even if ambitious policies are introduced in the near term. The required carbon price needed to achieve current targets has risen over time as policies have been delayed.*

- Illustration:

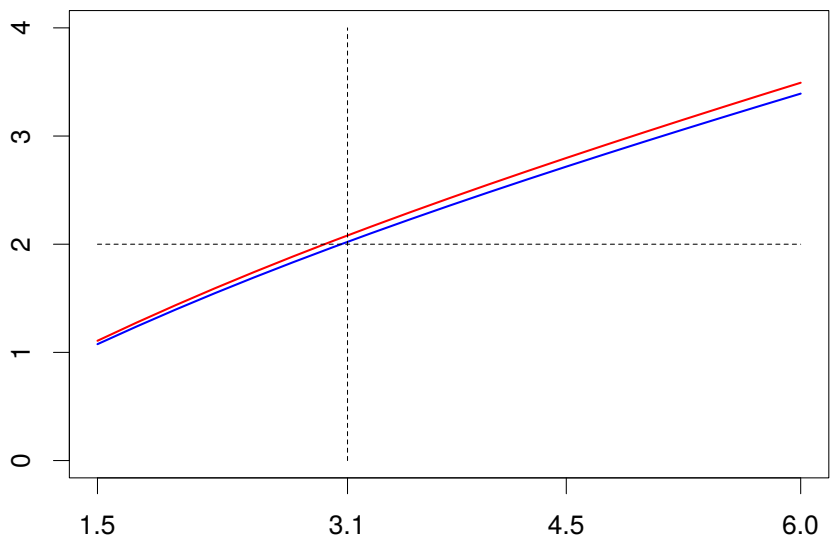


Figure: Temperature increase in 2100 as a function of the climate sensitivity whenever zero net emission is reached in 2016 (blue line) or 2018 (red line).

[2] http://cowles.yale.edu/sites/default/files/files/pub/d20/d2057.pdf

Coping with the Collapse –

Which shape for the carbon price (1/2)?

- A generalized logistic path:

$$\frac{\dot{p_C}}{p_C} = \beta_{p_C}\left(1 - \gamma_{p_C}\frac{p_C}{p_{BS}}\right),$$

with, $\beta_{p_C} > 0$, and $1 \geq \gamma_{p_C} \geq -1$.

- Set of carbon price paths considered

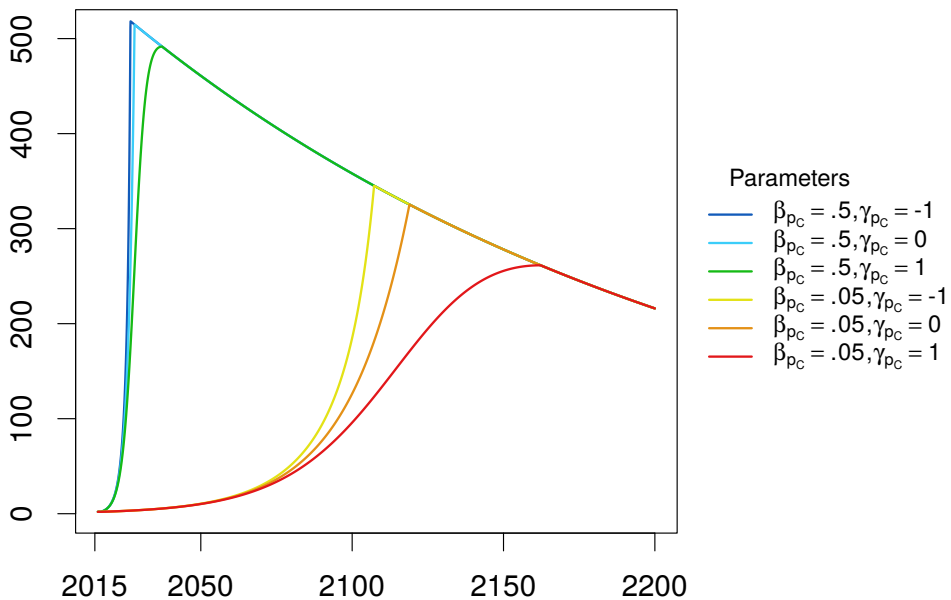


Figure: The carbon price for the boundaries conditions and included exponential cases.

Coping with the Collapse –

Which shape for the carbon price (2/2)?

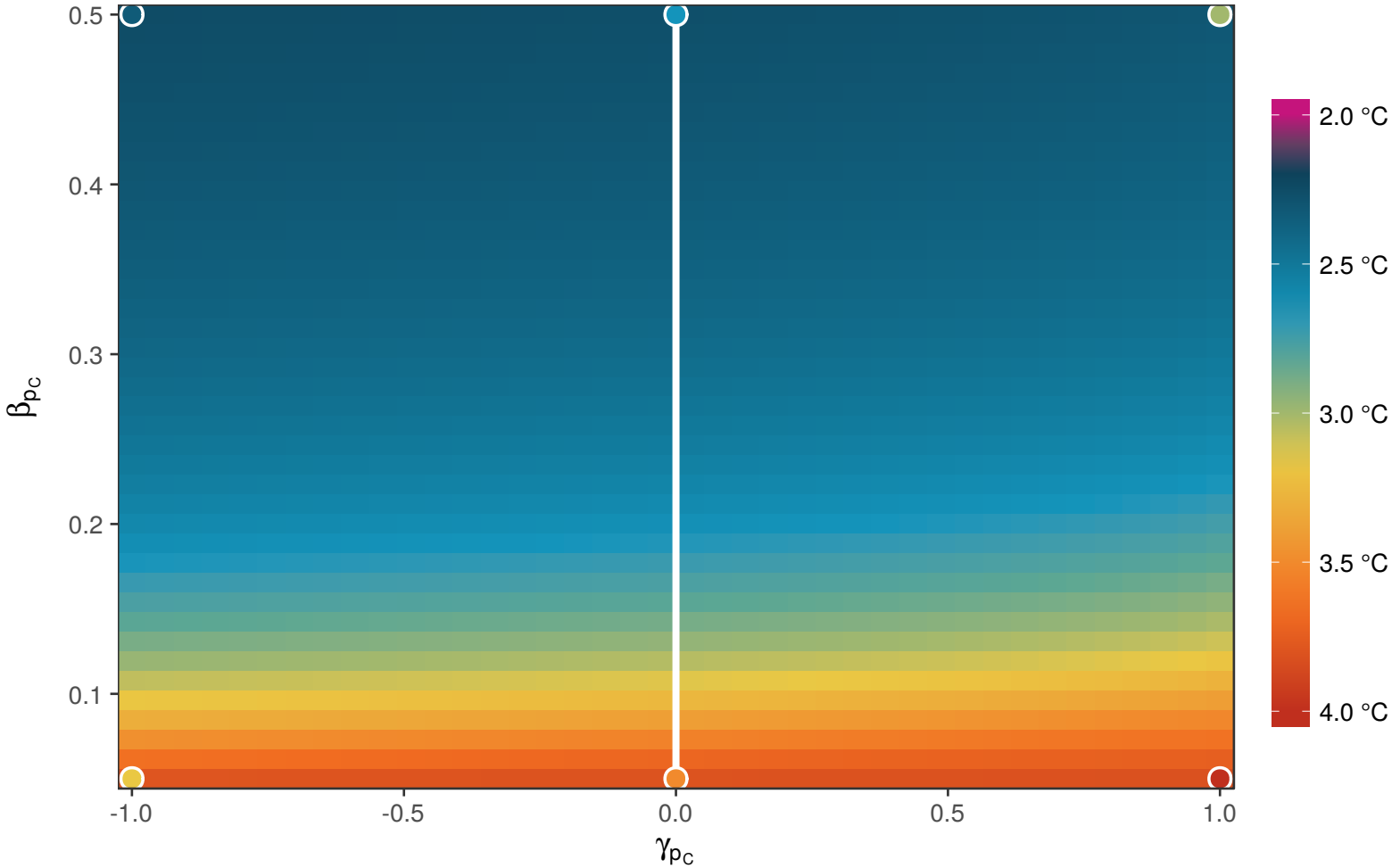


Figure: Heatmap in 2100 depending on the carbon price path in the Type 3 scenario (exponential case in the white line).

Coping with the Collapse –

New achievements goals: +3° C and +2.5° C in 2100

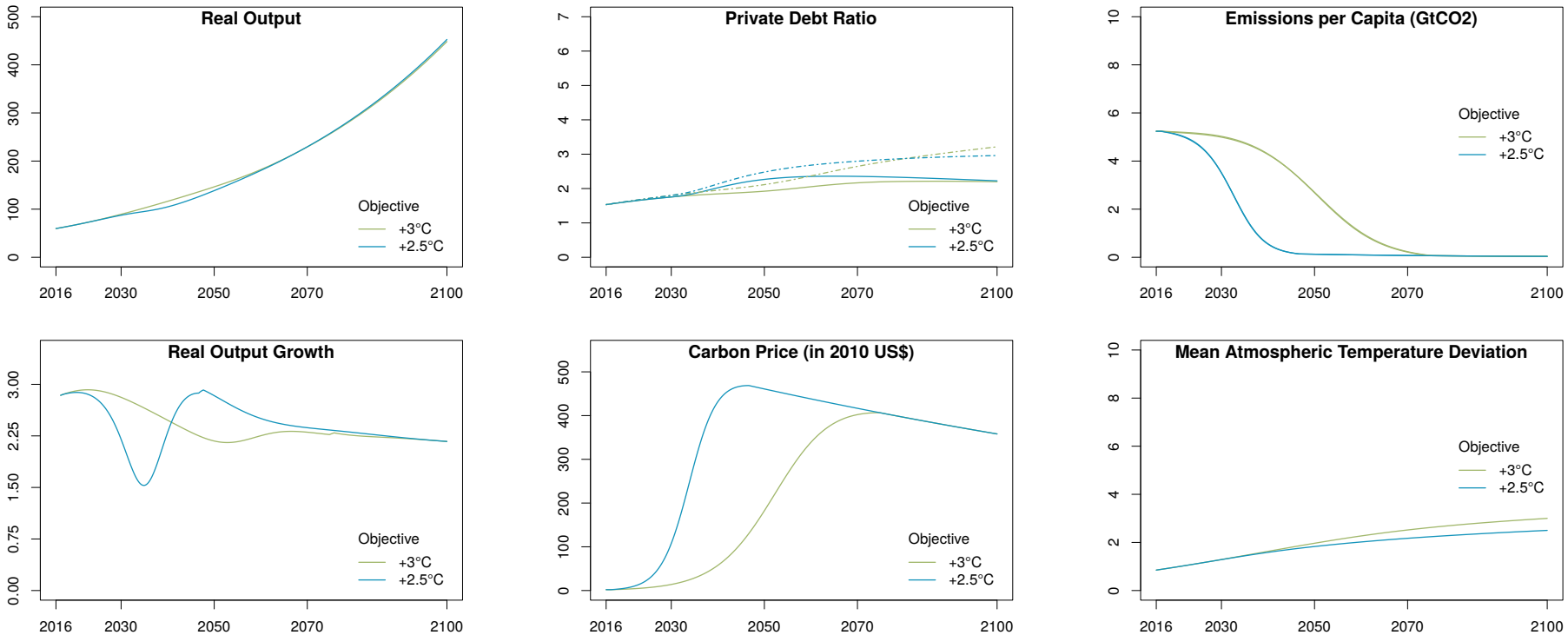


Figure: Trajectories of the main simulation variables for the Type 1 scenario compatible with policy objectives of +2.5°C and +3°C (in dashed line, the trajectories for the private debt ratio in the Type 3 scenario).

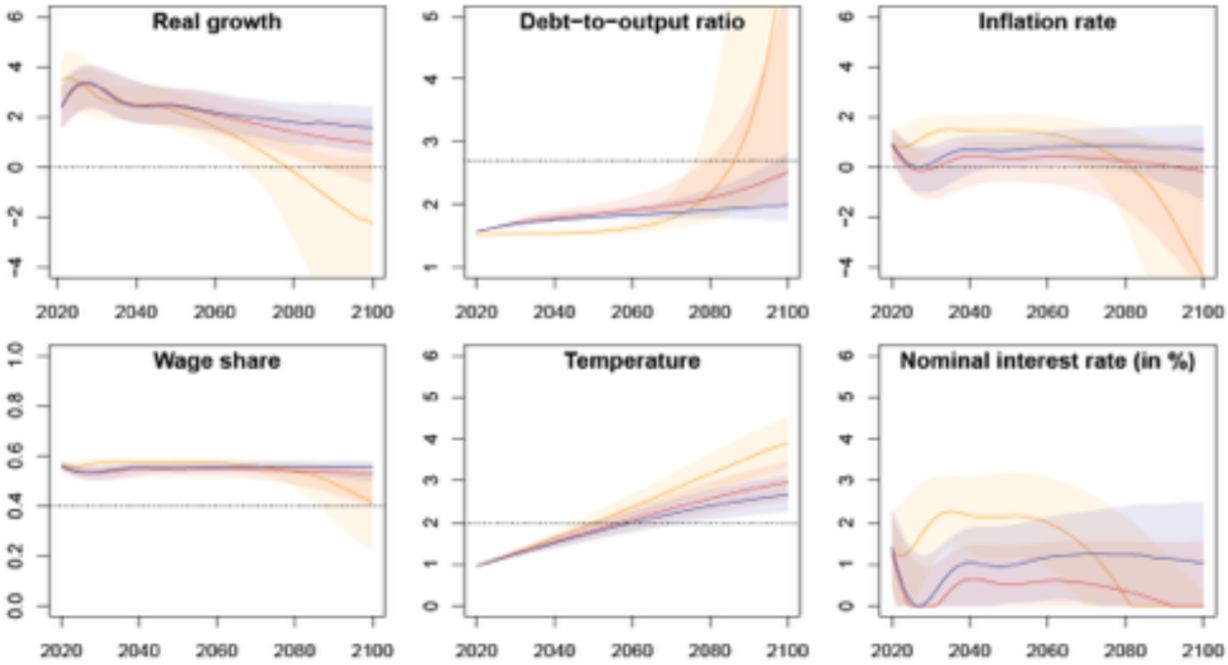
Outlines

Coping with the Collapse

A stochastic extension

GEMMES Monde

Rétroaction macroéconomie-climat



Scénario 1 (orange) : Absence d'intervention publique ;
Scénario 2 (rouge) : Mise en place d'une taxe carbone (tranche haute de la recommandation du rapport de la commission Stern-Stiglitz) ;
Scénario 1 (bleu) : Taxe carbone du Scénario 2 avec une subvention du secteur publique pour la décarbonation ;

Coping with the Collapse

Publications

ELSEVIER

Ecological Economics

Volume 147, May 2018, Pages 383-398

Analysis

Coping With Collapse: A Stock-Flow Consistent Monetary Macrodynamics of Global Warming

Emmanuel Bovari [b, c], Gaël Giraud [a, b, c], Florent Mc Isaac [a, c]

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Coping With Collapse, Ecological Economics, Volume 147, 2018, Pages 383-398.

ELSEVIER

International Economics

Available online 19 February 2018

In Press, Corrected Proof

Debt and damages: What are the chances of staying under the 2°C warming threshold?

Emmanuel Bovari [a, c], Oskar Lecuyer [b], Florent Mc Isaac [b, c]

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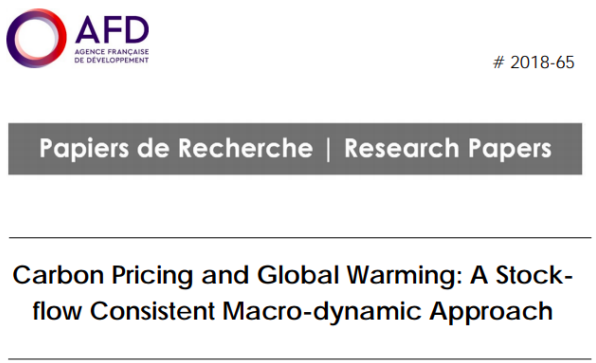
Debt and damages: What are the chances of staying under the 2C warming threshold? International Economics, 2018.



AFD

AGENCE FRANÇAISE DE DÉVELOPPEMENT

2018-65

Papiers de Recherche | Research Papers

Carbon Pricing and Global Warming: A Stock-flow Consistent Macro-dynamic Approach

Carbon Pricing and Global Warming, AFD Research Papers

Coping with the Collapse

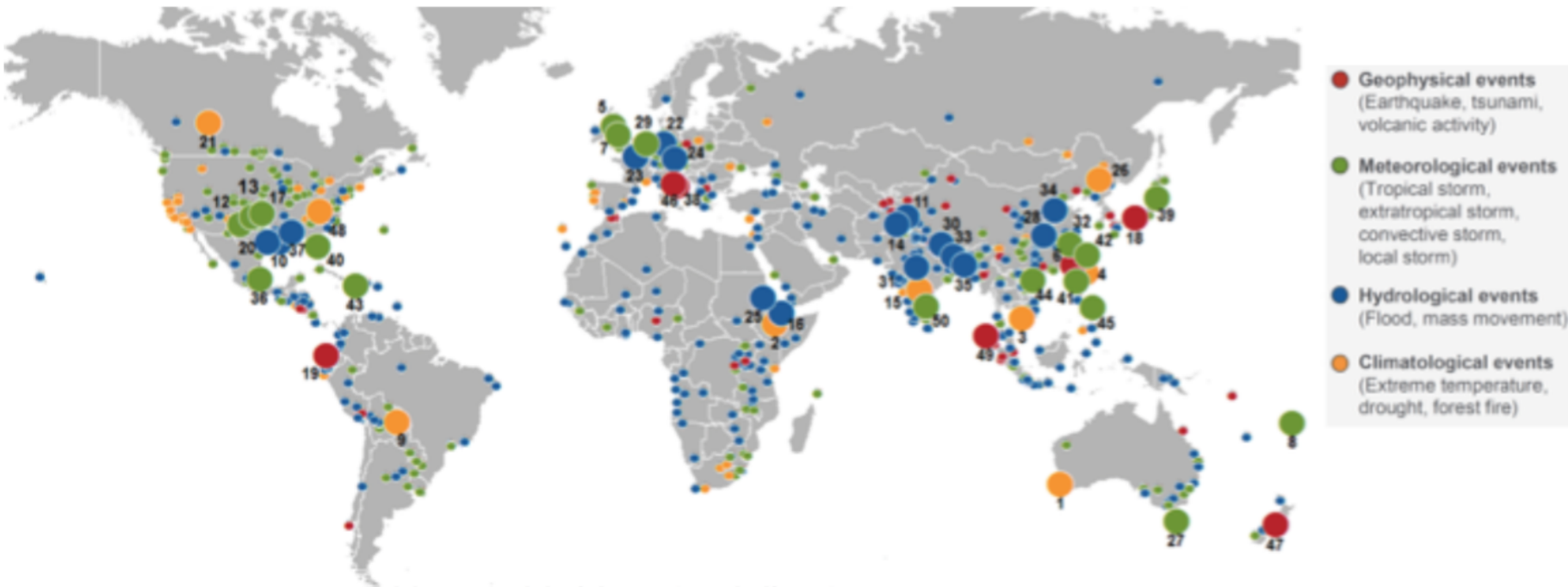
Areas for further research

- Endogenous technical progress.
- Substitution between capital and labour (McIsaac, 2018)
- Decoupling between demand and supply (Devrim et al.)
- Distinguish between various vintages of capital (Giraud and Lojkine, 2018)
- Endogenous population (de)growth (Victor Court et al., 2018)
- Empirical estimation of aggregate behavioural functions via polynomials and non-Gaussian residuals (Vodouris)
- Adding energy, minerals and other natural resources into the production function (Rostom, 2018)
- Adding expectations (Dosseto, 2018).
- The role of income and capital inequality (Giraud and Grasselli, 2017).

Coping with the Collapse

Climate change induces significant losses

- 1,900 loss events in 2016, overall loss amount in 2016 climbed to US$ 175bn
- **93% of all events are weather related**
- **Number of events causing economic losses has tripled between 1980 and 2014.**
- In 2016, **only 30% of 2016 weather-related loss events are insured.**



2015 worldwide natural disasters

Source : Munich Re 2016

Coping with the Collapse

Climate change induces significant losses

The example of the 2011 Thailand floods

An economic cost estimated at more than 45 billions of dollars whose only 22% were insured:
9,859 factories closed, 1,700 roads destroyed or paralysed, etc.

Direct and indirect impacts on:

The automotive industry

- **6,000** cars not produced each day in the Thai car factories
- **67 M$** the cost incurred by Nissan to restore its production line
- **50%** decrease in production of Honda's factories in the US and Canada

The electronic industry

- **45%** of hard disks in the world were produced in Thailand in 2011
- **235 M$** the loss for the industrial company Western Digital
- **x2** the increase in hard disk prices following the floods

***Source**: Riverside (2012)*

Coping with the Collapse

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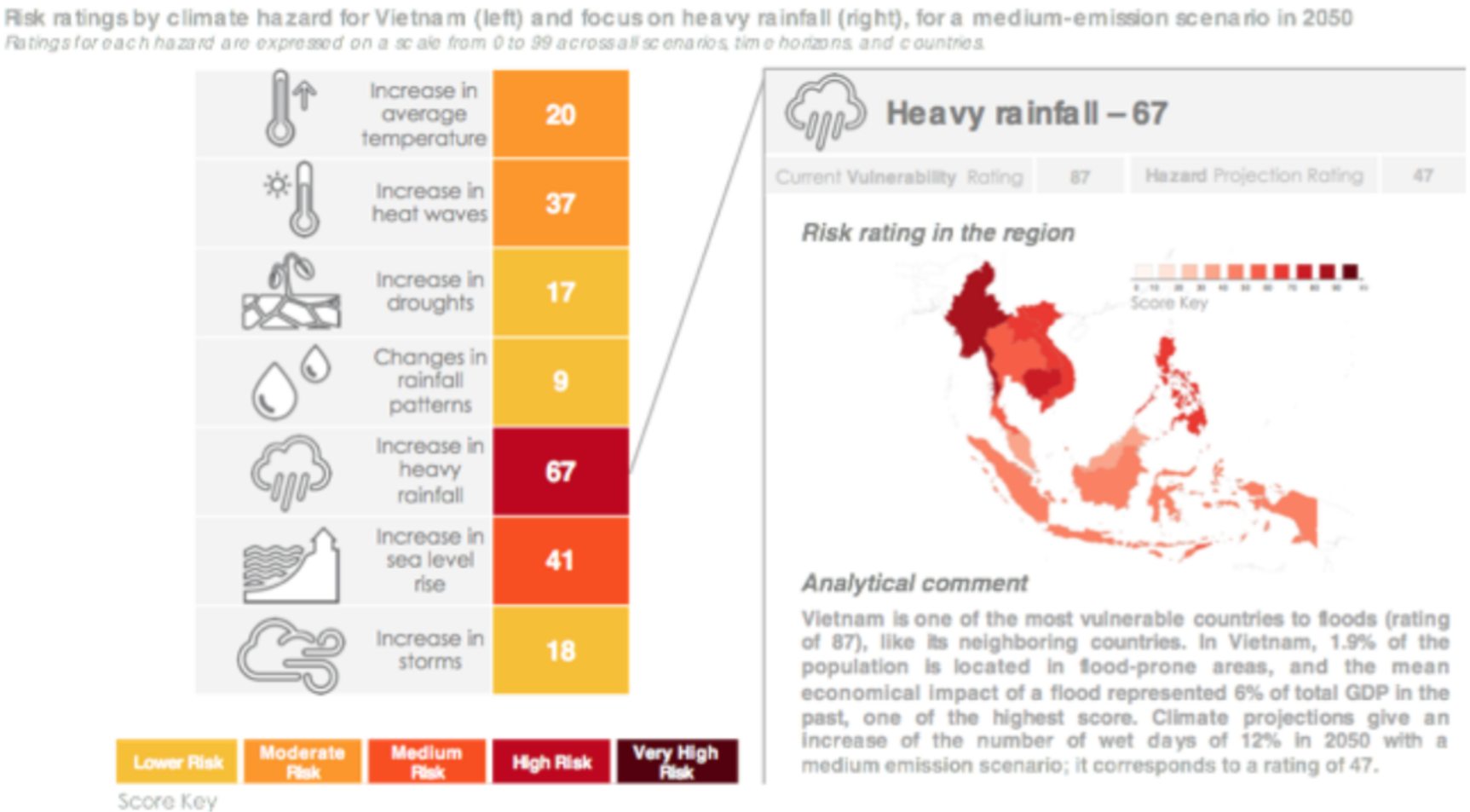

Extrait d'une analyse souveraine : Note de risque multi-aléa et focus sur les précipitations extrêmes pour le Vietnam en 2050

Notes de risque CRIS souveraine selon le scénario moyennement émissif à horizon 2050

Coping with the Collapse

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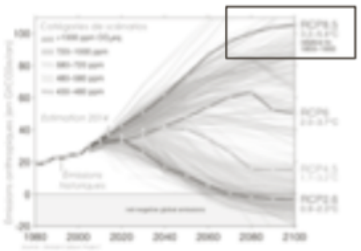
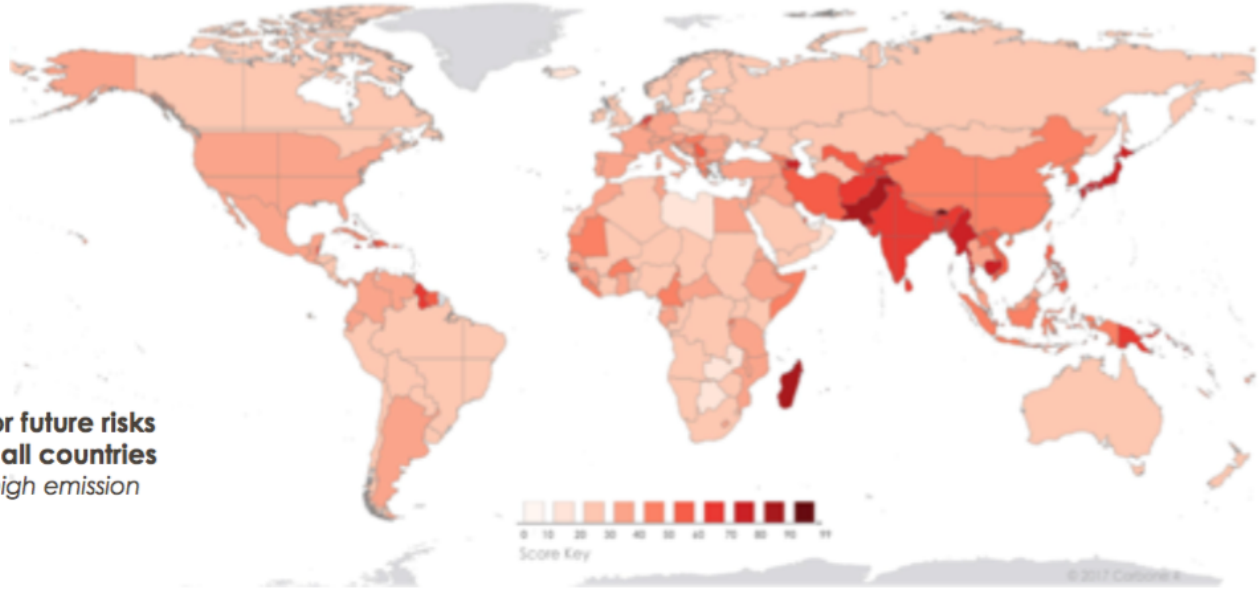
- With an average warming scenario of 4°C at the end of the century and taking into account the 7 direct climate hazards of the CRIS method :
  - **The countries most at risk account for 11% of the world economy** and 28% of global population.
  - **These countries are mainly located in Asia, the Pacific and the Indian Ocean**, they are particularly exposed and vulnerable to the intensification of flooding, sea level rise and storms.





Distribution map of CRIS ratings for future risks coming from climate change for all countries

CRIS multi-hazard risk ratings fun for high emission scenario in 2100

Back to thermo

Georgescu-Roegen

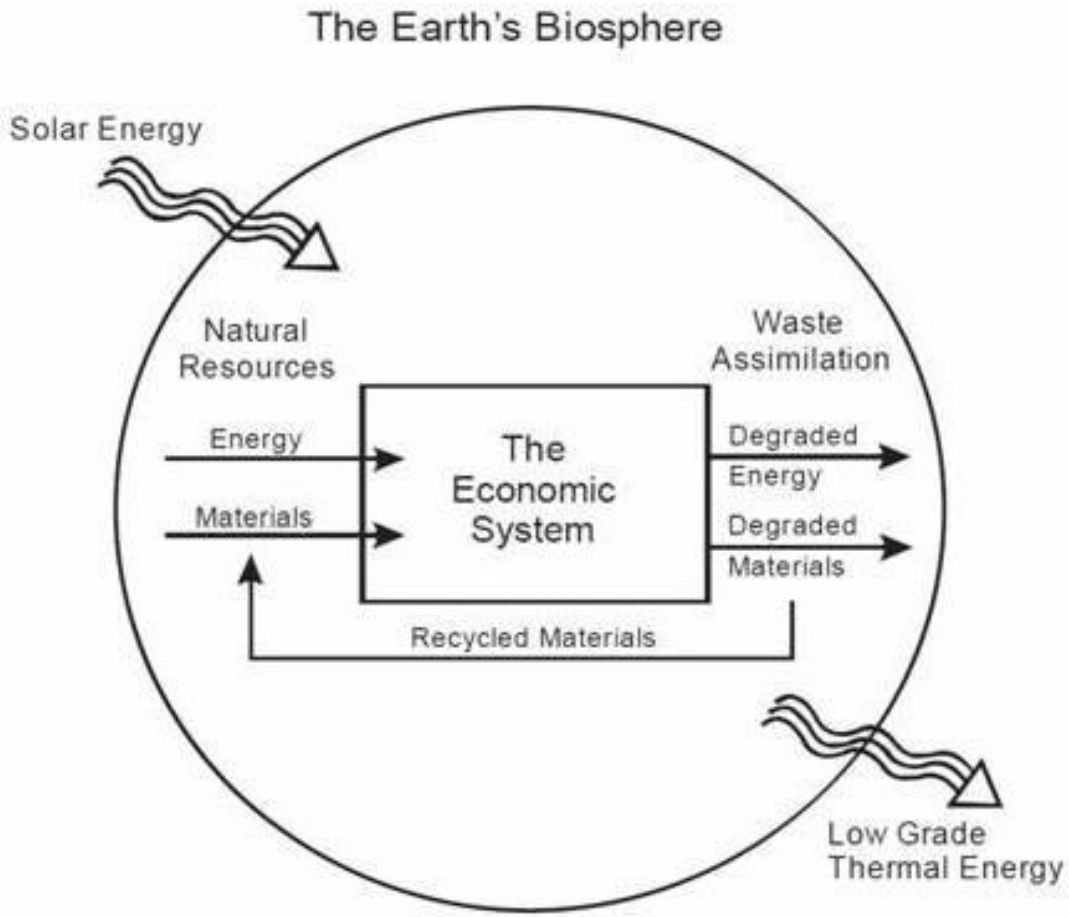


Figure:

Back to thermo

Useful work (generalization of mechanical work)

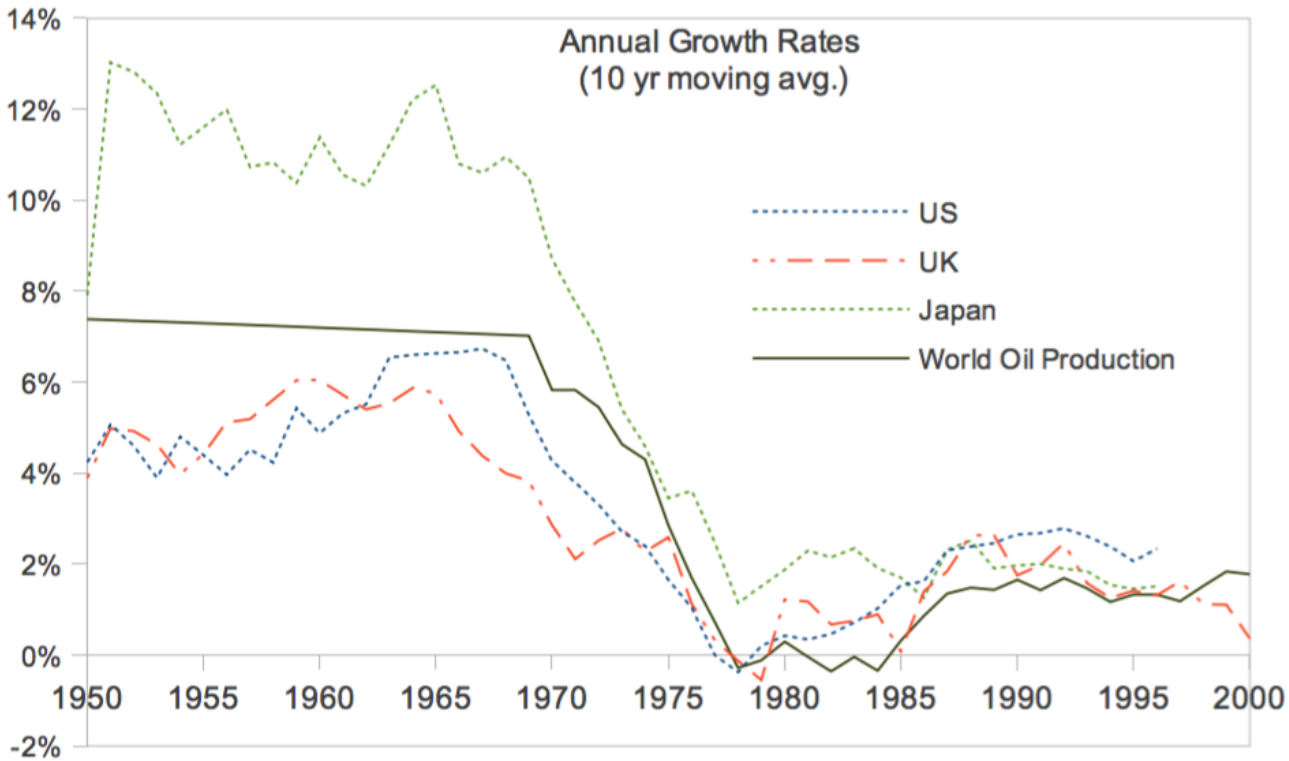


Figure 13: Useful Work per Capita and World Oil Production. Source: See Appendix.

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Flix (2014)

Back to thermo

- Eric Herbert et alii. 2018

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- Economy = Aggregate metabolism (dissipative structure) that extracts ressources R, produces useful work, and rejects wastes, W.

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- Ecosystem = Reservoir where R and W coexist.

  $\overline{\mu}_R$:= potential (chemical, exergetic...) of R in the ecosystem.

  $\overline{\mu}_W$:= potential of W in the ecosystem.

  $\overline{\mu}_R > \overline{\mu}_W$ (far from thermo equilibrium? Mallick (2014)).
  Virgo (2011).

Back to thermo

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- $\dot{N}_R$ (resp. $\dot{N}_W$) = rate of flow of R (resp. W) across the "membrane" between the economic metabolism and the ecosystem.

- When econ and thermo meet:

$$\dot{N}_R \quad = \quad D_R(\overline{\mu}_R - \mu_R) - M \tag{1}$$

μ_R := potential of the resource within the economic metabolism

T := constant temperature (e.g., T= 287 K, Svirezhev (2000))

D_R : diffusion parameter, $\frac{D_R(\overline{\mu}_R - \mu_R)}{T}$= diffusion between environment and the economic metabolism

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- In an ideal solution, chemical potential:

$$\mu_X = \mu_{X_0} + RT \ln N_X$$

R = 8.31 $JK^{-1}\text{mol}^{-1}$ gas constant. N_X: molar concentration.

- Any potential that is an increasing function of concentration.
  T constant in the ecosystem (to be relaxed).

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  $D_W > 0$.

  Pollution = exergy left in our wastes (Ayres).

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  T constant in the ecosystem (to be relaxed).
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  $D_W > 0$.

  Pollution = exergy left in our wastes (Ayres).
- $\overline{\mu}_R > \mu_R = \overline{\mu}_R - \frac{M}{D_R} > \mu_W = \overline{\mu}_W + \frac{M}{D_W} > \overline{\mu}_W$

- Total entropy produced by the economic metabolism per unit of R converted into W:

$$d\Sigma = \frac{\mu_R - \mu_W}{T} \tag{2}$$

$$= \frac{\overline{\mu}_R - \overline{\mu}_W - Mk}{T} \tag{3}$$

with $k := \frac{1}{D_R} + \frac{1}{D_W}$.

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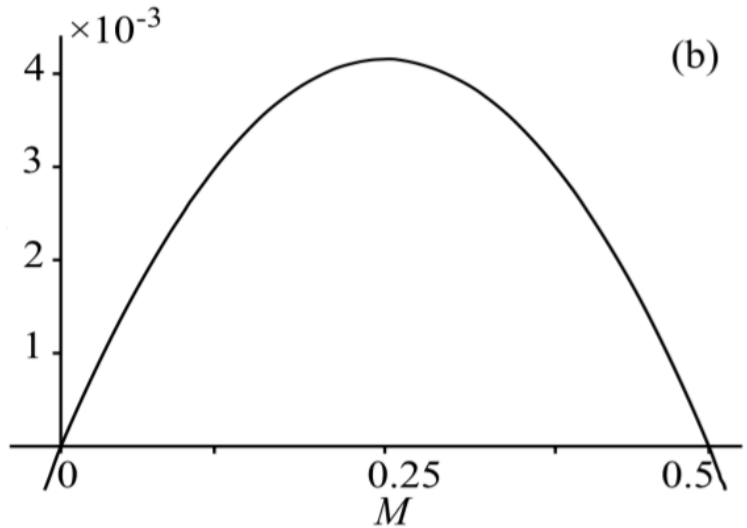
with $k := \frac{1}{D_R} + \frac{1}{D_W}$.

- $M^{\max} = \frac{\overline{\mu}_R - \overline{\mu}_W}{k} \quad \Rightarrow d\Sigma = 0$. No useful work.

Converting R to W faster than $M^{\max}$ would require work to be done rather than being a source of work. (generalization of EROI). Virgo and Harvey (2011), Odum and Pinkerton (1955).

- Total entropy produced by the economic metabolism:

$$dS := Md\Sigma = \frac{\overline{\mu}_R - \overline{\mu}_W - kM}{T} M.$$



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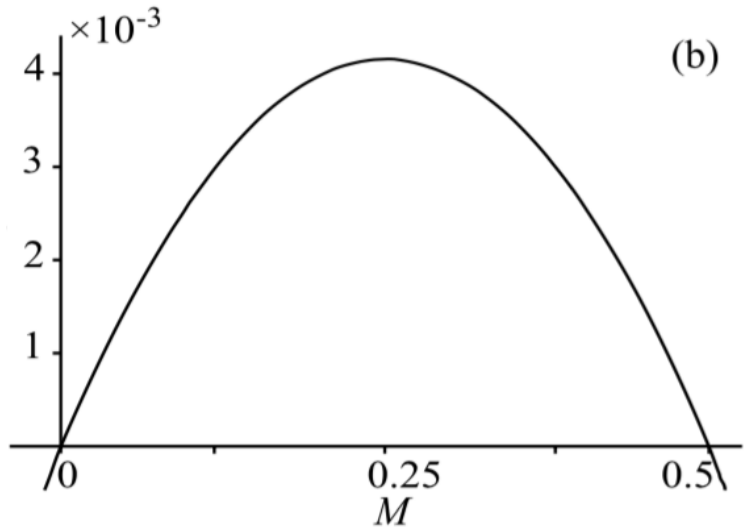

- Conversely, $\overline{\mu}_R - \overline{\mu}_W = Mk \Rightarrow d\Sigma = dS = 0$. No useful work either.

  Cf. Eric Herbert et alii (2018): where it is shown why $\overline{\mu}_R - \overline{\mu}_W \to 0^+$.

“Red Queen” effect.

Lewis Caroll, Leigh van Valen (1973).