TOPOLOGIE et GEOMETRIE
en
ECONOMIE

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SCIENCES DU VIVANT
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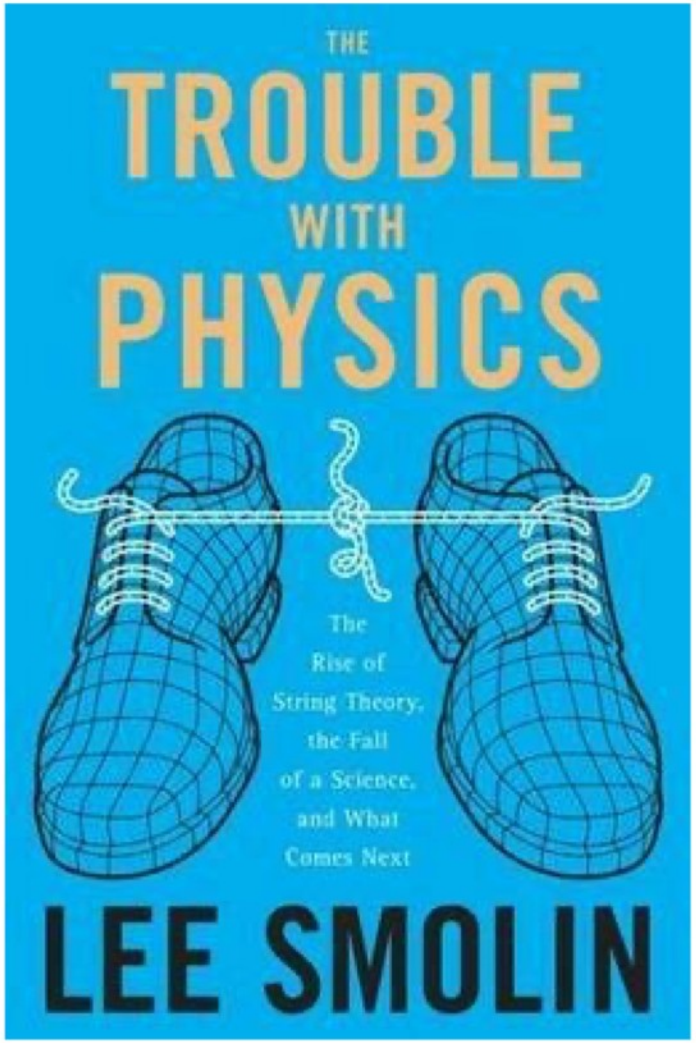
Paris Interdisciplinary Energy Research Institute

Tribalization of science?



(2006)

The Trouble With Macroeconomics

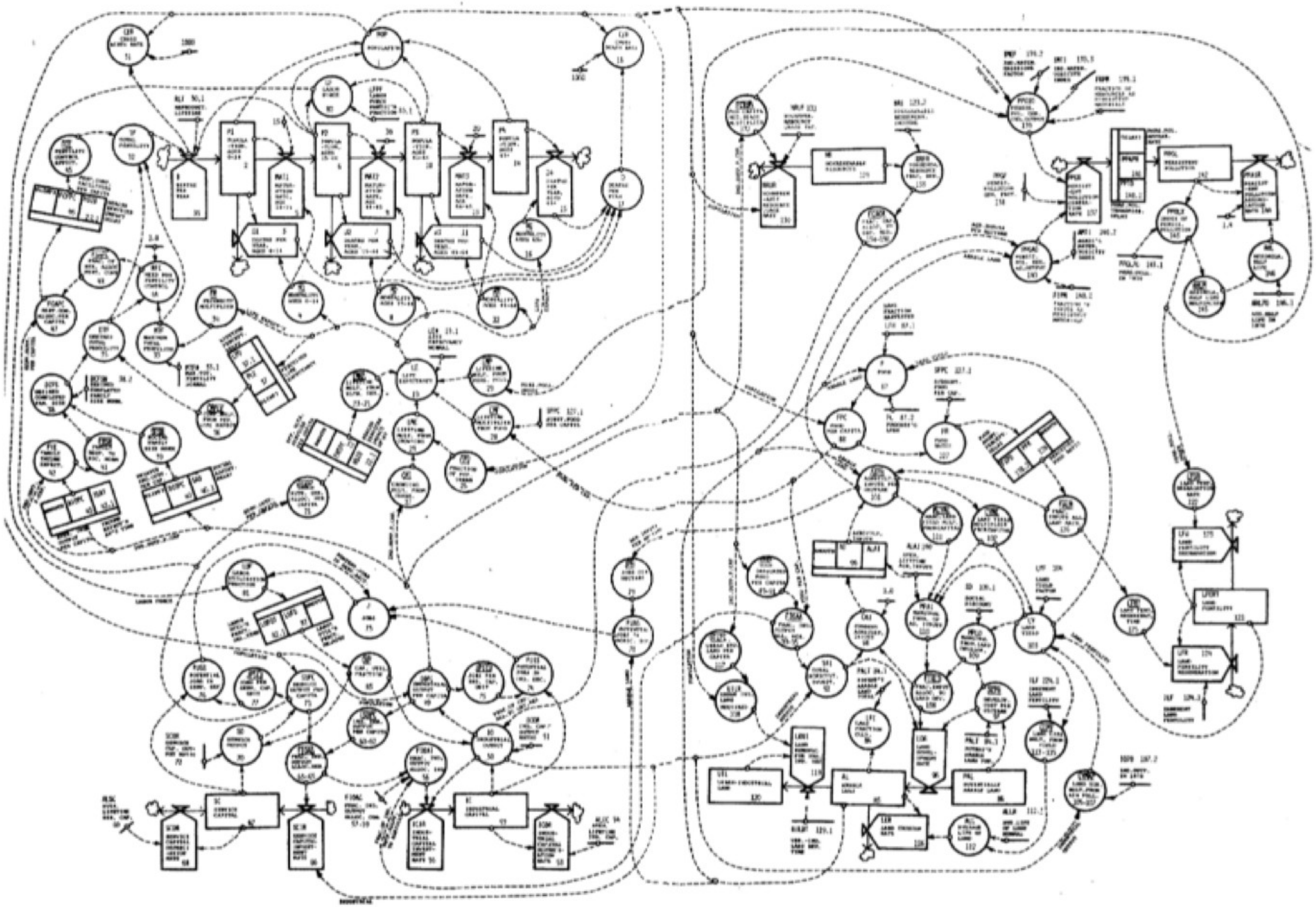
PAUL ROMER
Stern School of Business
New York University

Wednesday 14th September, 2016

Abstract

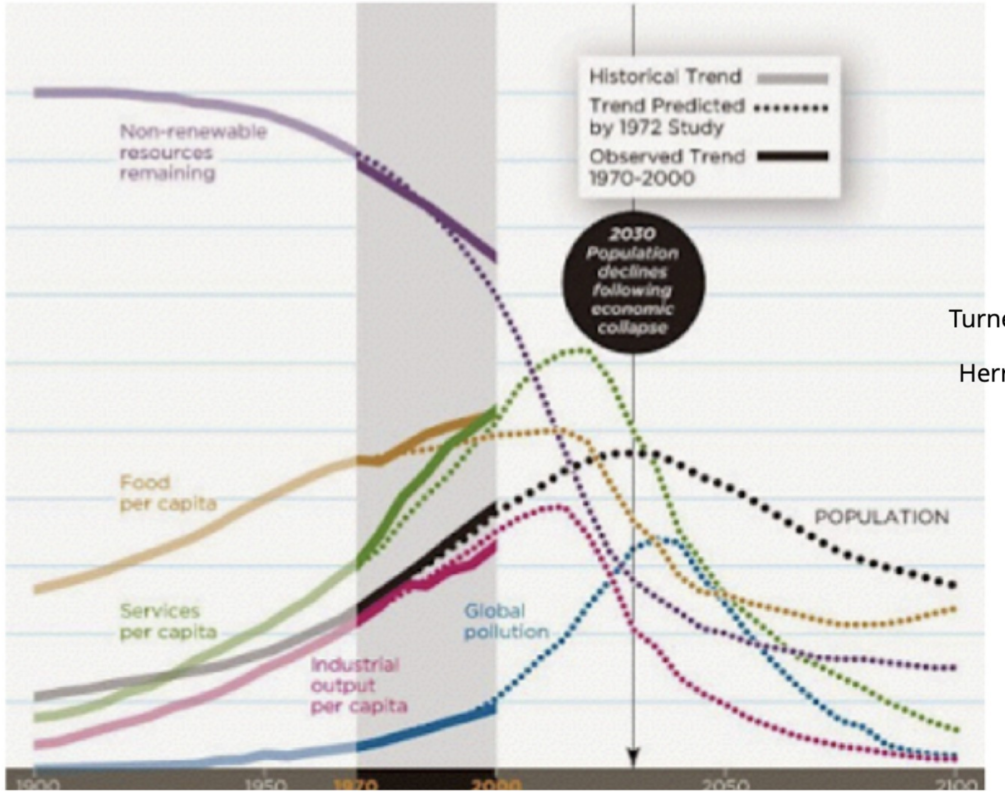
For more than three decades, macroeconomics has gone backwards. The treatment of identification now is no more credible than in the early 1970s but escapes challenge because it is so much more opaque. Macroeconomic theorists dismiss mere facts by feigning an obtuse ignorance about such simple assertions as "tight monetary policy can cause a recession." Their models attribute fluctuations in aggregate variables to imaginary causal forces that are not influenced by the action that any person takes. A parallel with string theory from physics hints at a general failure mode of science that is triggered when respect for highly regarded leaders evolves into a deference to authority that displaces objective fact from its position as the ultimate determinant of scientific truth.

Delivered January 5, 2016 as the Commons Memorial Lecture of the Omicron D
Epsilon Society. Forthcoming in *The American Economist*.



World 3

- Back-testing : Ce que ne font presque jamais les économistes car nos modèles ont des performances catastrophiques au-delà de deux ans. (Et seulement pour les VaR)
- Mais, dans World3, pas une ligne d'économie : or ce sont bien les prix, les prof
l'économie



Turner (20

Herringt

I. COMPLEXITY ECONOMIES

Arthur, *Nature* (2021)
Beinhocker 2006
Elsner 2004

Giraud (2021) forthcoming *Handbook of Complexity Economics*
Giraud & Swilling, *ibid.*

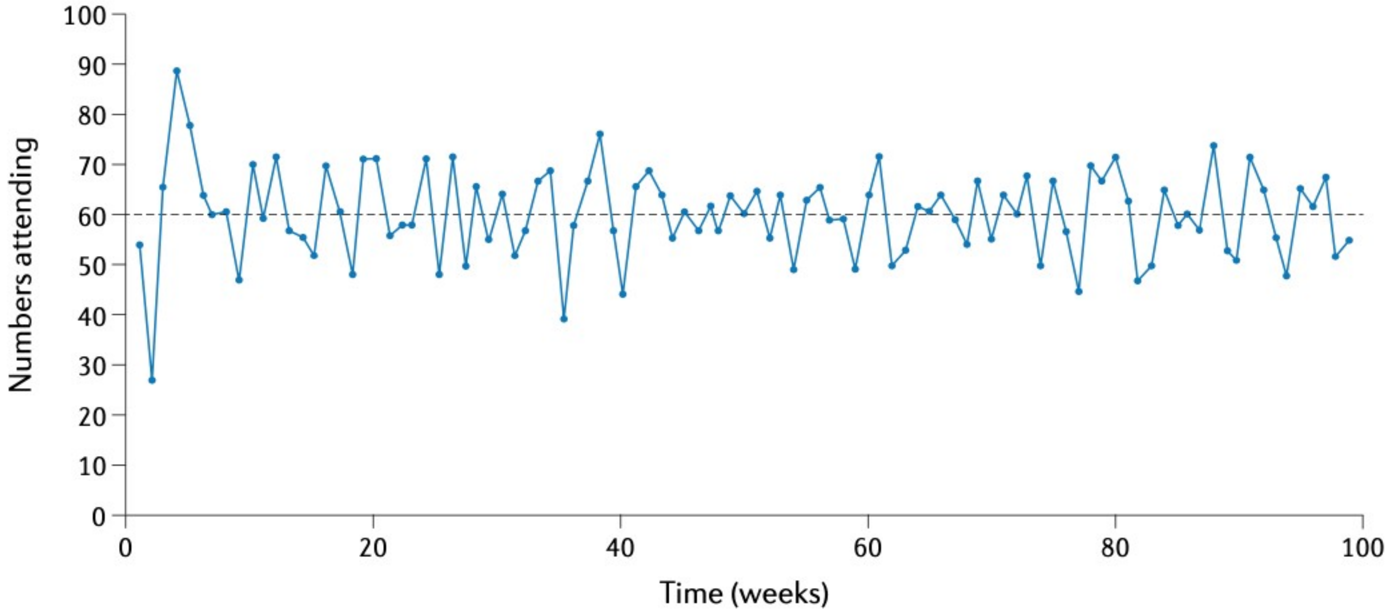


Fig. 1 | **Attendance at the El Farol bar in the first 100 weeks.** Agents attend if they believe the total attendance that week will be no more than 60. Each creates their own set of plausible hypotheses or predictors of attendance, and, every week, acts on their currently most accurate one. Figure reprinted with permission from REF.[12], AAAS.

Stock-flow consistency

	Households	Firms		Banks	Sum
Balance Sheet					
Capital stock		$+pK$			$+pK$
Inventory		$+cV$			$+cV$
Deposits	$+M$			$-M$	0
Loans		$-D$		$+D$	0
Sum (net worth)	X_h	X_f		X_b	X
Transactions		current	capital		
Consumption	$-pC_h$	$+pC$		$-pC_b$	0
Capital Investment		$+pI_k$	$-pI_k$		0
Change in Inventory		$+c\dot{V}$	$-c\dot{V}$		0
Accounting memo [GDP]		$[Y_n]$			
Wages	$+W$	$-W$			0
Depreciation		$-p\delta K$	$+p\delta K$		0
Interest on deposits	$+r_m M$			$-r_m M$	0
Interest on loans		$-rD$		$+rD$	0
Profits		$-\Pi$	$+\Pi$		0
Financial Balances	S_h	0	$S_f - p(I_k - \delta K) - c\dot{V}$	S_b	0
Flow of Funds					
Change in Capital Stock		$+p(I_k - \delta K)$			$+p(I_k - \delta K)$
Change in Inventory		$+c\dot{V}$			$+c\dot{V}$
Change in Deposits	$+\dot{M}$			$-\dot{M}$	0
Change in Loans		$-\dot{D}$		$+\dot{D}$	0
Column sum	S_h	S_f		S_b	$pI_k + c\dot{V}$
Change in net worth	$\dot{X}_h = S_h$	$\dot{X}_f = S_f + \dot{p}K + \dot{c}V$		$\dot{X}_b = S_b$	$\dot{X}$

Table 1: Balance sheet and transactions flows

A (non-linear) out-of-equilibrium Dynamical system

Akerlof & Stiglitz (1969)

Grasselli & Costalima (2012)

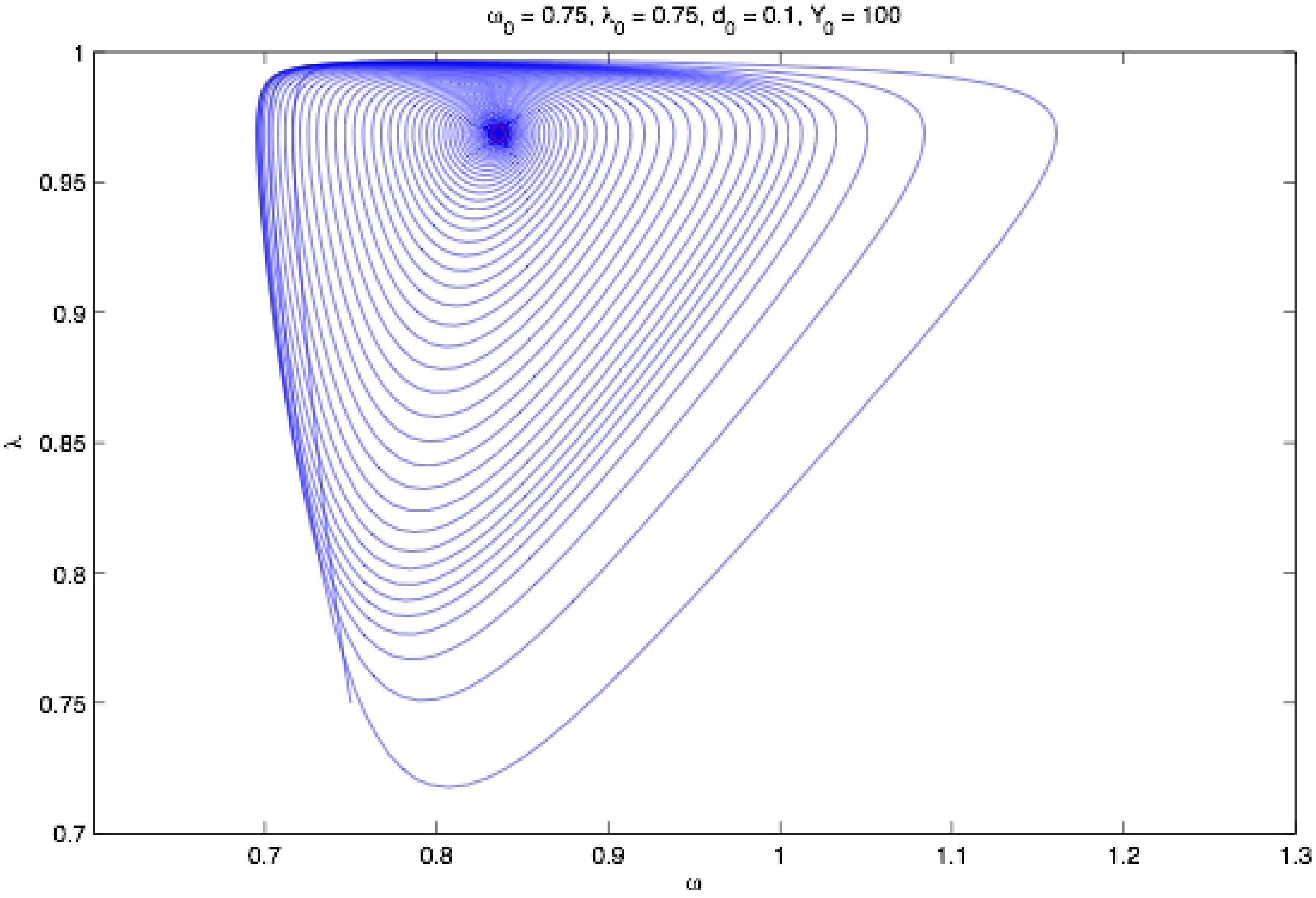
Grasselli &Nguyen (2013)

Grasselli et al. (2018)

Giraud & Grasselli (2019)

Bovari, Favre & McIsaac (2019)

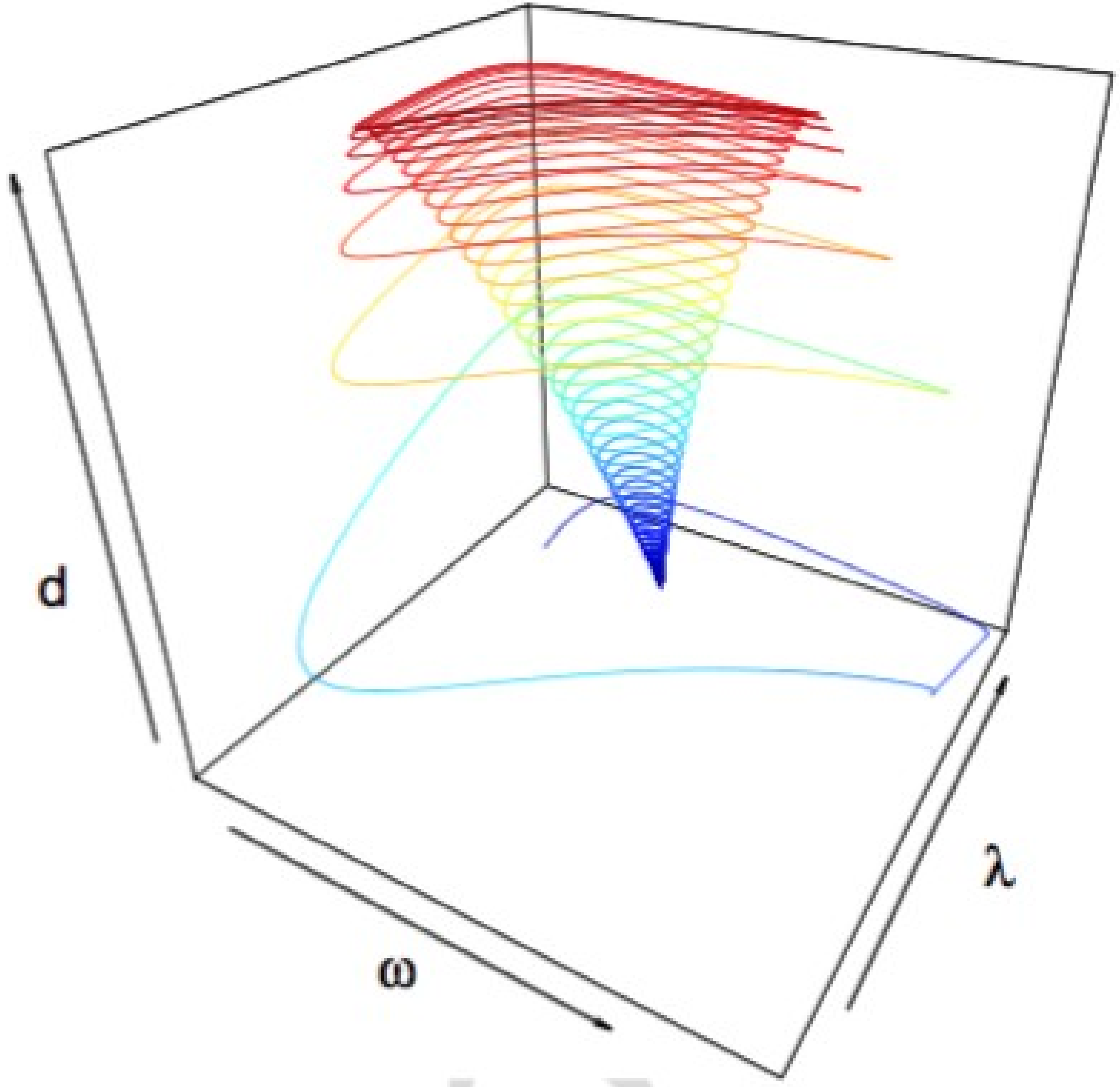
Dossetto & Giraud (2022a) forthcoming



A multidimensional setting

Basic version: 3d

Giraud & Dossetto (2022b) : 10d



General properties I

- Private debts matter
- Endogenous business cycles
- Multiple equilibria
- A balanced growth path satisfying the Golden rule: Solow's equilibrium
- A (Fisherian) debt-deflationary equilibrium, cf. Giraud & Pottier (2013, 2015)
- Traditional Philips trade-off in the long-run: inflation vs employment

General properties II

- Too wide income inequalities lead to the deflationary equilibrium via the debt channel, Giraud& Grasselli (2021)

- r > g does NOT imply more inequality

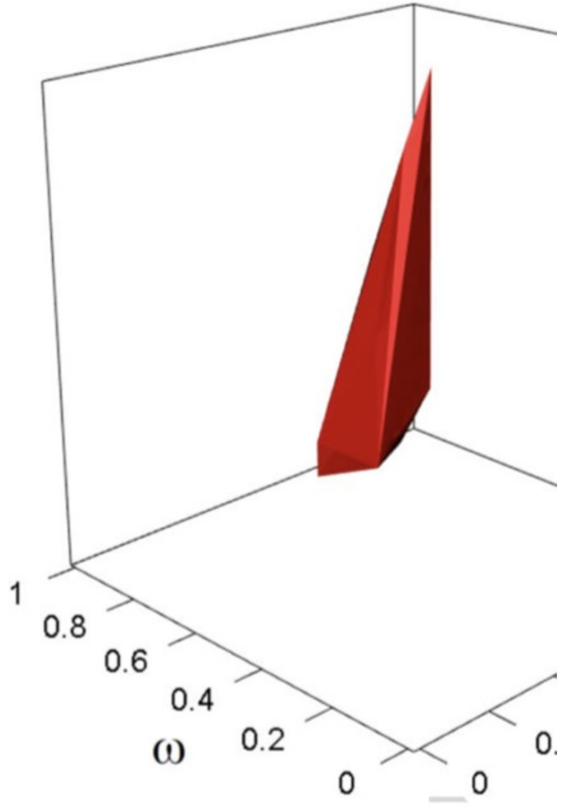
Piketty (2014), Giraud (2014), Acemoglu & Robinson (2015)

- r > g is a necessary condition of stability for the ‘bad’ equilibrium.

- When converging to a debt-deflationary equilibrium, income velocity --> 0 Giraud & Dossetto (2021b)

- Embedding into a thermodynamical set-up, Giraud, Noel et al., forthcoming.

Fig. 8 Basin of attraction of the *good* equilibrium for the Leontief production technology. The *good* equilibrium point is $(\omega, \lambda, d) = (0.865, 0.972, 1.50)$



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' equilibrium
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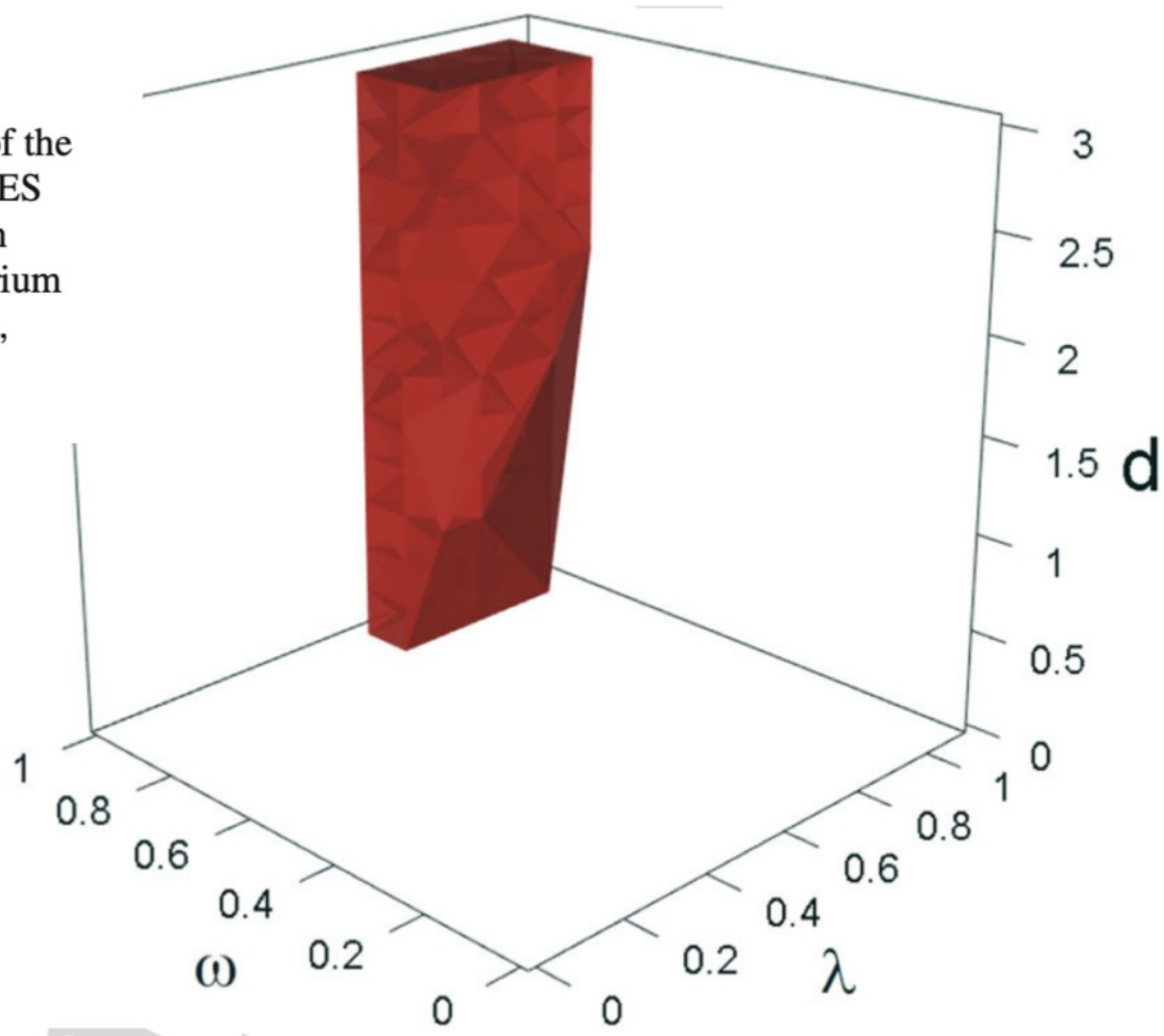
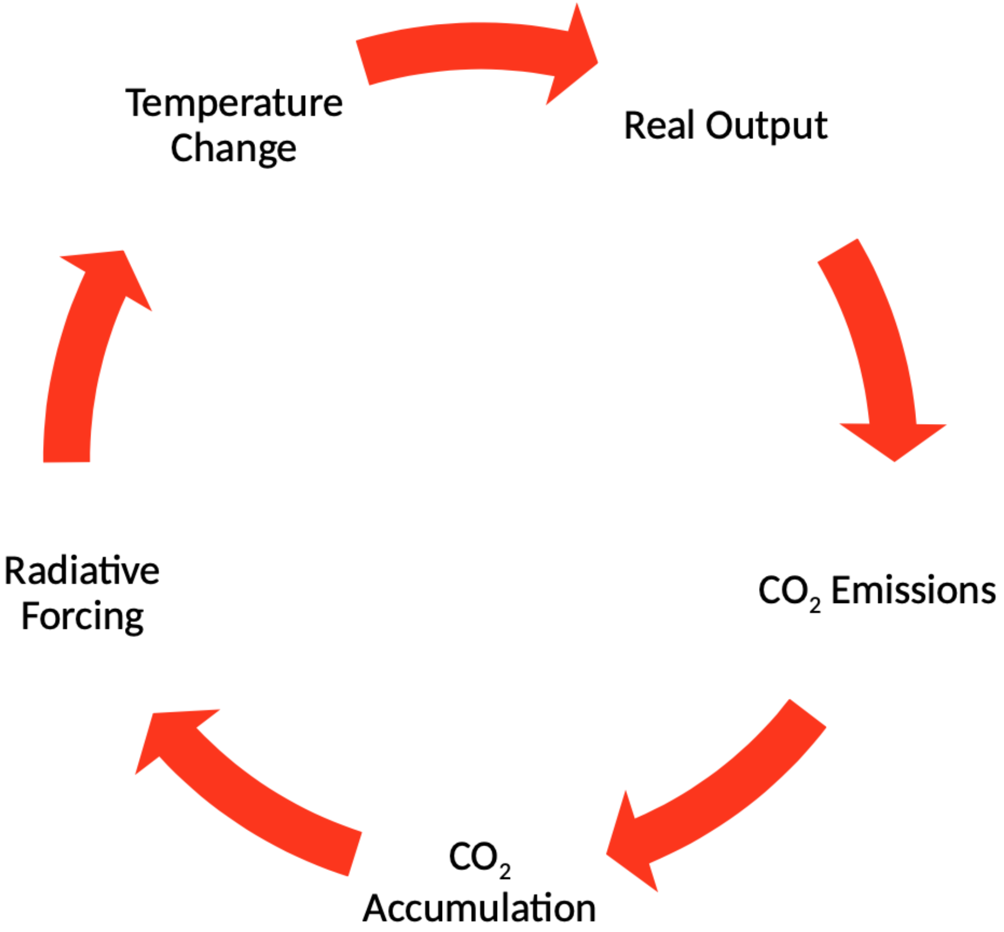


Bastidas et al. (2(

A world version

- Calibration over a reconstructed world economy ($\simeq$ 85% of the "real" world) with a panel of 36 countries over the period 2000 - 2015 (dataset from World Bank, Penn University, the Bureau of Economic Analysis and the UN).

A world version



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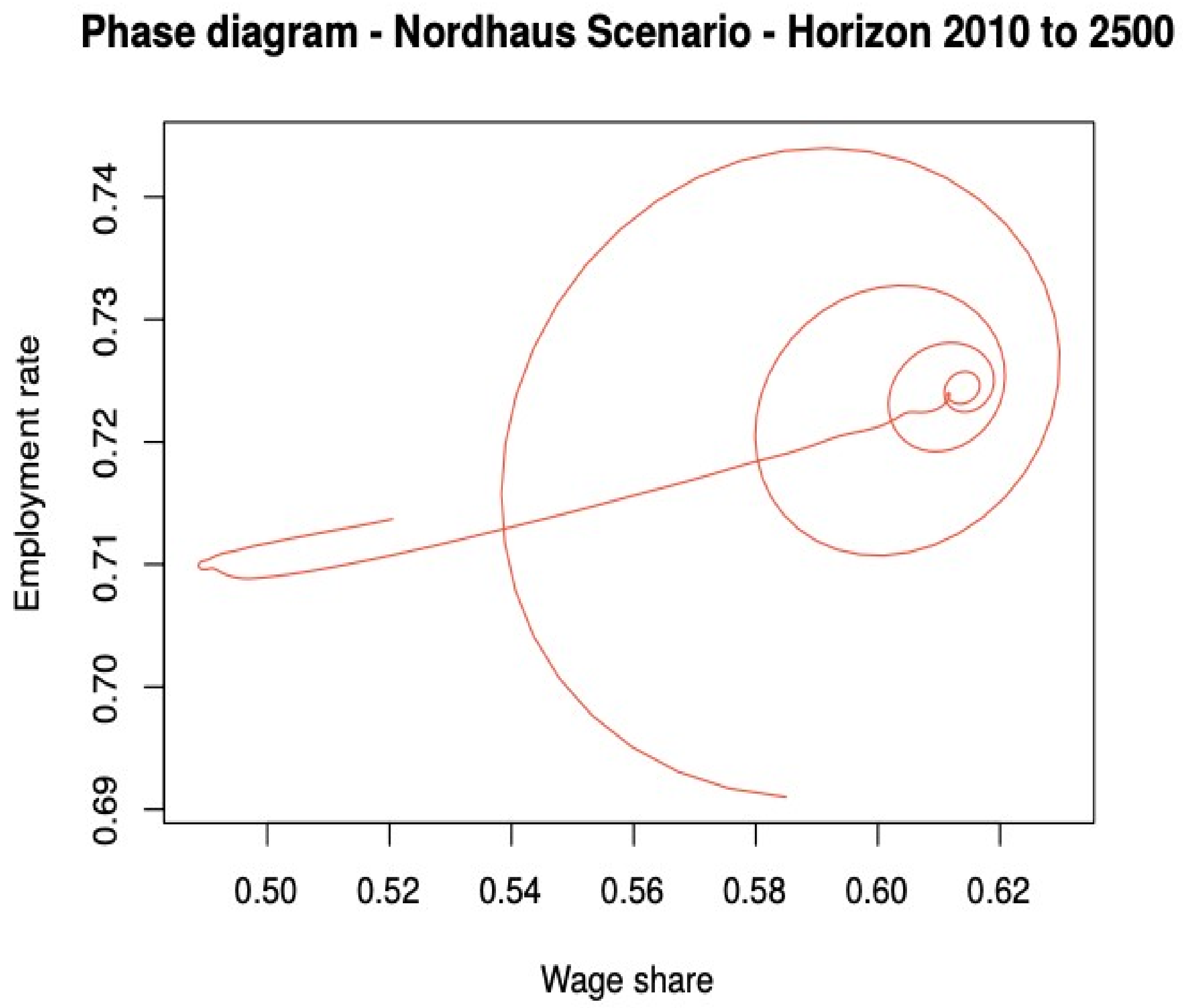
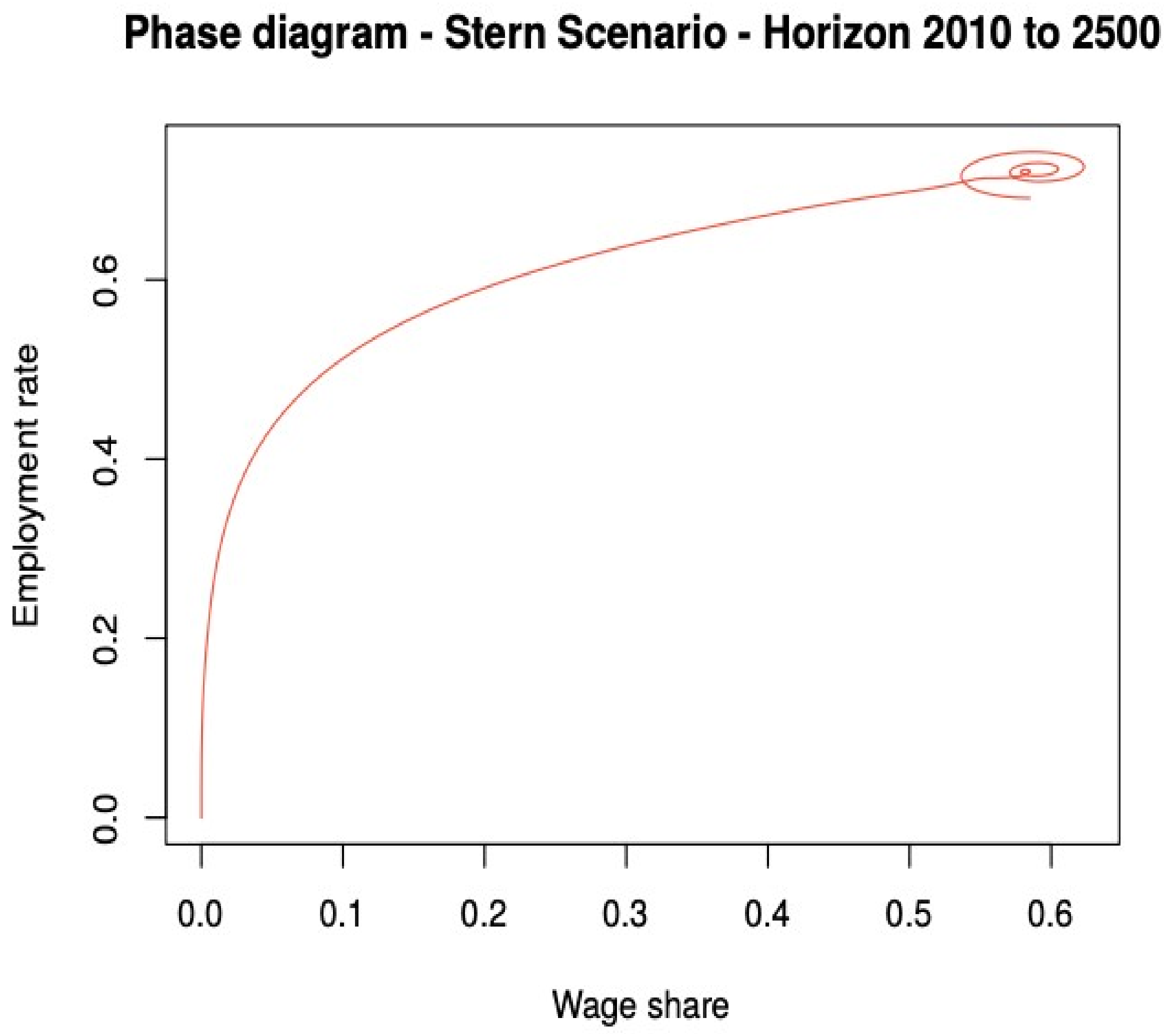
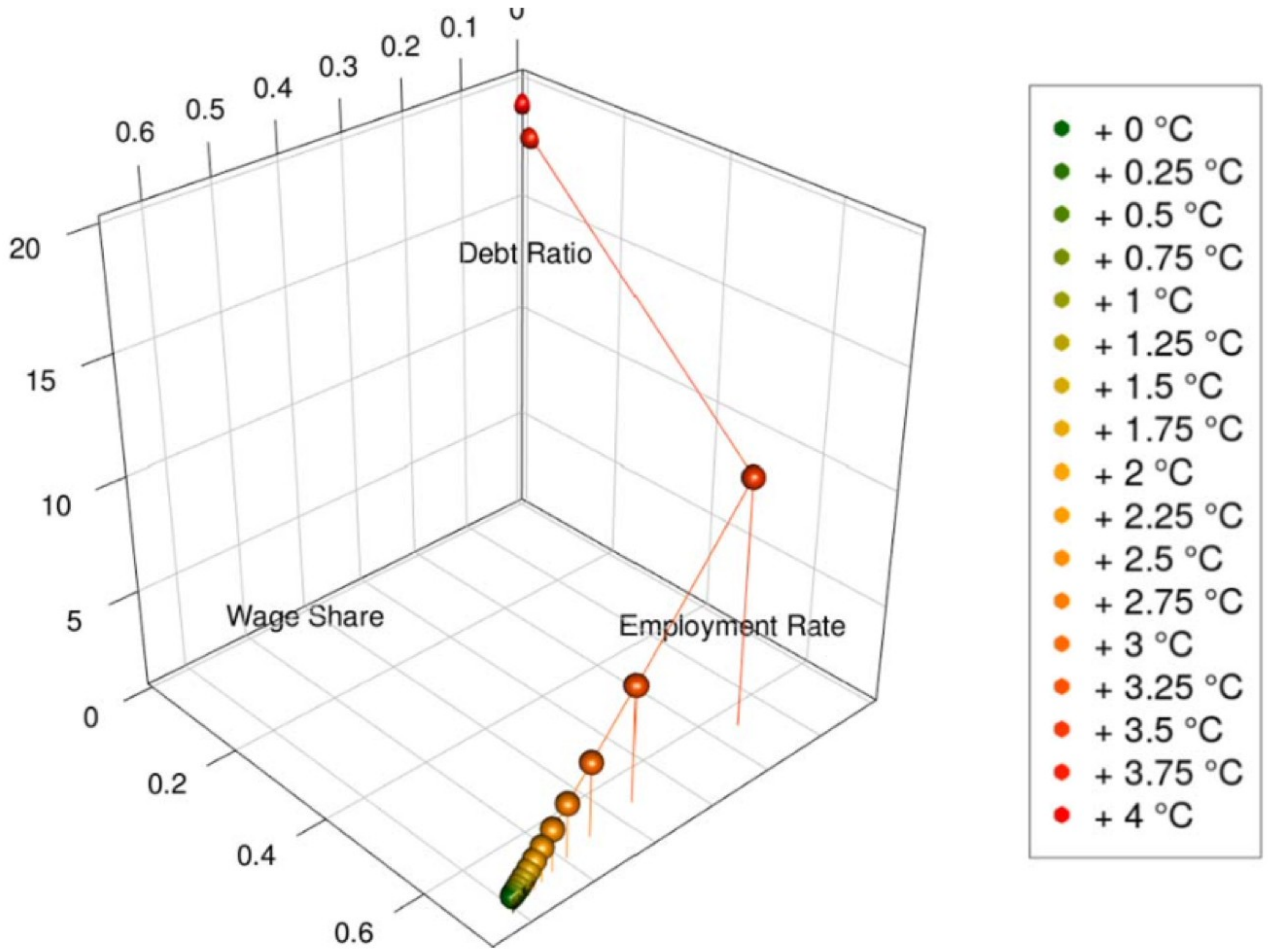
Climate change drives the economy out of the “good” basin of attraction

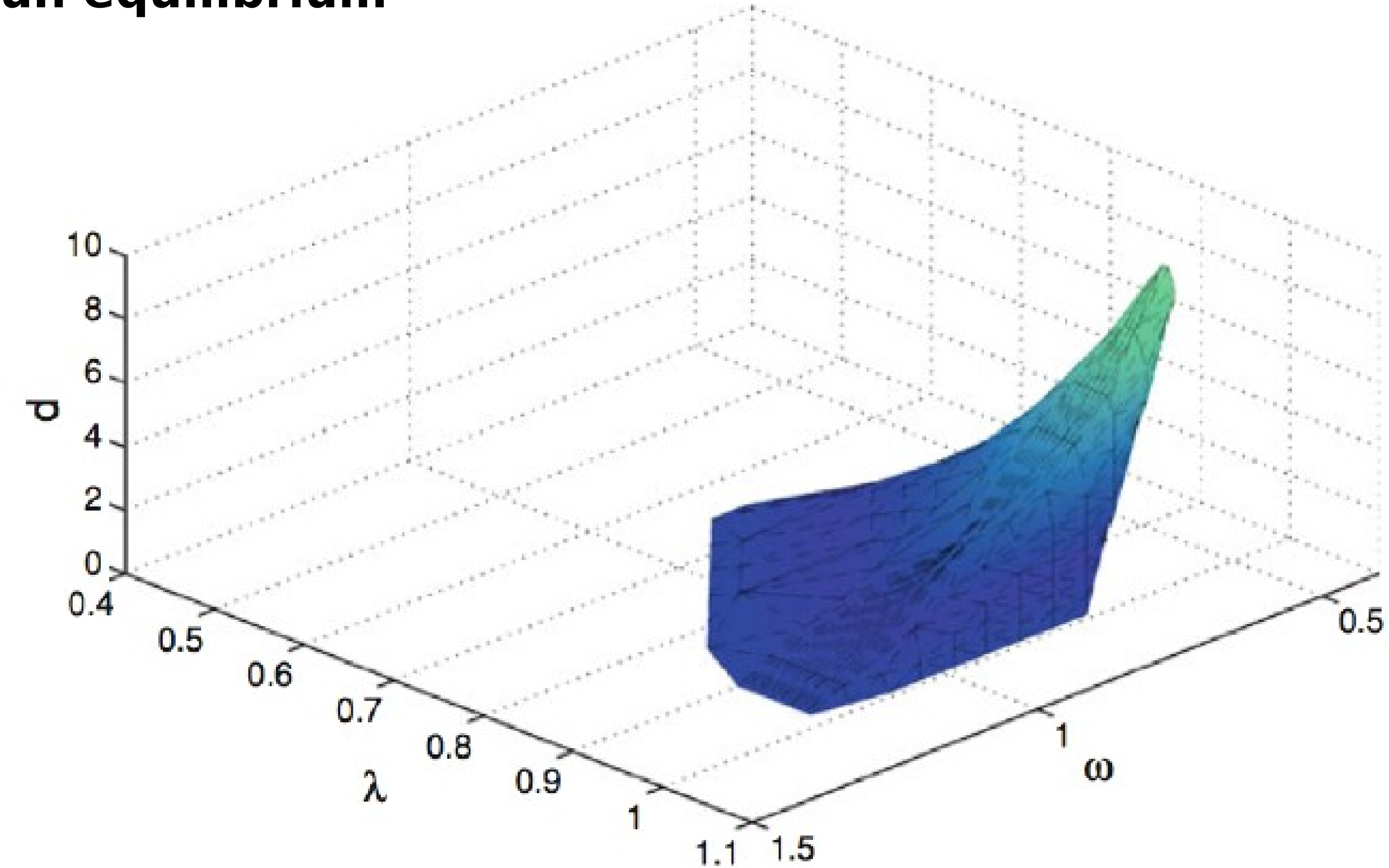






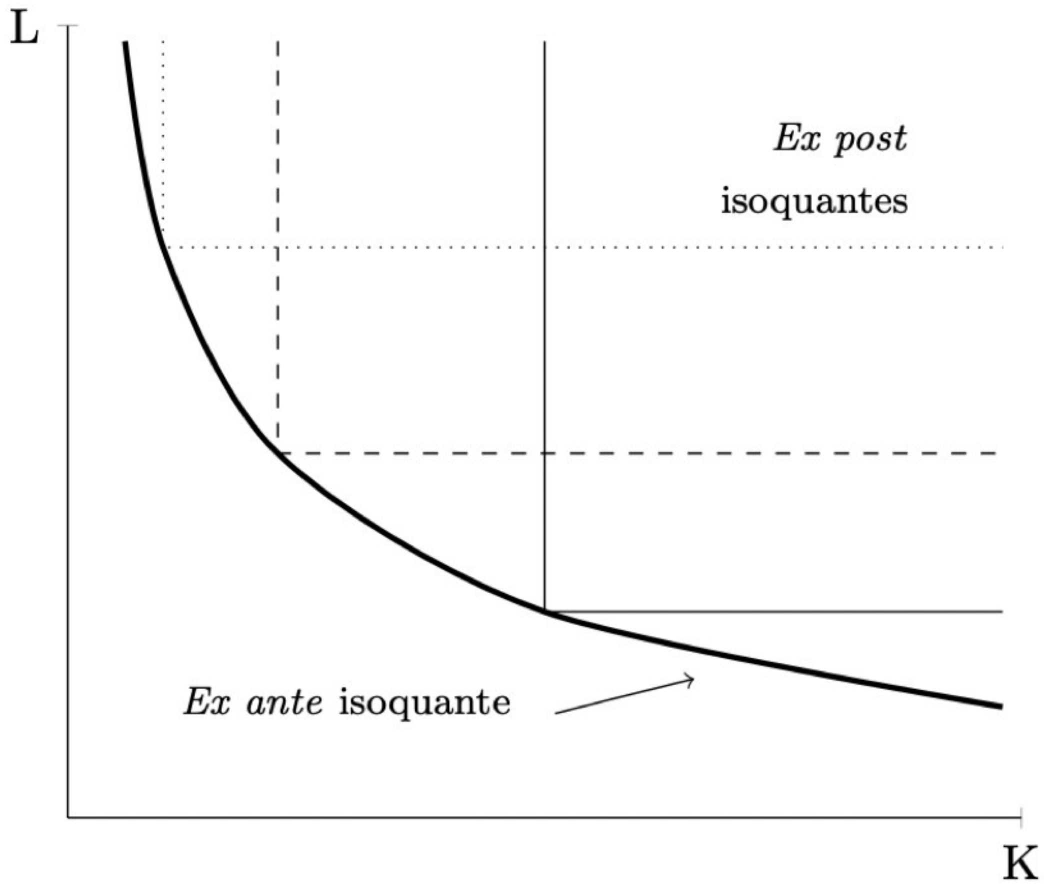
ig. 2. Solovian steady state as a function of temperature anomaly in the *High damage K* *:enario*.

Basin of attraction ("Watershed") of a long—run equilibrium



1 A more general set-up

$$Y := A\Big[bK^{-\eta} + (1-b)e^{\alpha t}L^{-\eta}\Big]^{-1/\eta}$$



$$Y_d := C + I,$$

$$\dot{V} := Y - Y_d.$$

$$Y_n := pY_d + c\dot{V},$$

i) $c := \mathbf{w}L/Y$, is the unit cost of production, with $\mathbf{w}$ being the unitary money wage and $W := \mathbf{w}L$, the wage bill.

ii) $c\dot{V}$, the change in inventories valued at their current production cost.

Denoting $\omega := \mathbf{w}L/pY$ the wage share, one gets

$$c = p\omega.$$

$$\Pi_f := Y_n - W - rD_f$$
$$= pC + pI + c\dot{V} - W - rD_f.$$

Corporate profits

$$\Pi_e := pY - W - rD_f.$$

Expected profits (myopia)

$$\Delta_f := \Delta\Pi_e$$

Corporate dividends

$$F_f = pC - \Delta_f - W - rD_f.$$

Actual money flow

$$\dot{D}_f = W + c\dot{V} + \Delta_f - pC + rD_f.$$

Corporate debts

$$\Pi_b := rD_f + rD_h.$$

Banks' profits

$$\Delta_b = \Pi_b.$$

Banks' dividends

$$\dot{D}_h = pC - W + rD_h - \Delta_b - \Delta_f = pC - W - rD_f - \Delta_f,$$

Households' debts

$$\dot{D}_f + \dot{D}_h = c\dot{V}.$$

Aggregate debts

	Households	Firms (Current)	Firms (Capital)	Banks	Row Sum
Balance sheet					
Capital stock		$+pK$			pK
Inventory		$+cV$			cV
Deposits	$+M_h$	$+M_f$		$-M$	0
Loans	$-L_h$	$-L_f$		L	0
Equity	E	$-E_f$		$-E_b$	0
Column sum (Net worth)	X_h	$X_f = 0$		$X_b = 0$	X
Transactions		Current	Capital		
Consumption	$-pC$	$+pC$			0
Investment		$+pI$	$-pI$		0
Change in Inventory		$+c\dot{V}$	$-c\dot{V}$		0
Depreciation		$-p\delta K$	$+p\delta K$		0
Wages	$+W$	$-W$			0
Interest on loans	$-rL_h$	$-rL_f$		$+rL$	0
Interest on deposits	$+rM_h$	$+rM_f$		$-rM$	0
Pre-dividend net profits		$-\Pi_f$	$+\Pi_f$		0
Dividends	$\Delta_f + \Delta_b$		$-\Delta_f$	$-\Delta_b$	0
Column sum (balances)	S_h	0	$S_f - p\dot{K} - c\dot{V}$	$S_b = 0$	0
Flows of funds					
Change in capital stock		$p\dot{K}$			$p\dot{K}$
Change in inventory		$c\dot{V}$			$c\dot{V}$
Change in deposits	$\dot{M}_h = 0$	$\dot{M}_f = c\dot{V}$		$-\dot{M} = -c\dot{V}$	0
Change in loans	$-\dot{L}_h$	$-\dot{L}_f$		$+\dot{L}$	0
Column sum (savings)	S_h	S_f		$S_b = 0$	$p\dot{K} + c\dot{V}$
Change in firm equity	$+\dot{E}_f$	$-(S_f + \dot{p}K + \dot{c}V)$			0
Change in bank equity	$+\dot{E}_b$			$-S_b$	0
Change in net worth	$\dot{E} + S_h$				$\widehat{\dot{pK}} + \widehat{\dot{cV}}$

Aggregate Behaviour

$$d_f := D_f/pY$$

Corporate debt ratio

$$\omega := \mathbf{w}L/pY$$

Wage share

$$\nu(\omega) := \frac{K}{Y} = \frac{1}{A}\Big(\frac{1-\sigma\omega}{b}\Big)^{-1/\eta},$$

Endogenous capital-output ratio

$$\pi = 1 - \omega - rd_f + \frac{cV}{pY} = 1 - \omega y_d - rd_f.$$

Profit share

$$\pi_e := \frac{\Pi_e}{pY} = 1 - \omega - rd_f - \delta\nu(\omega).$$

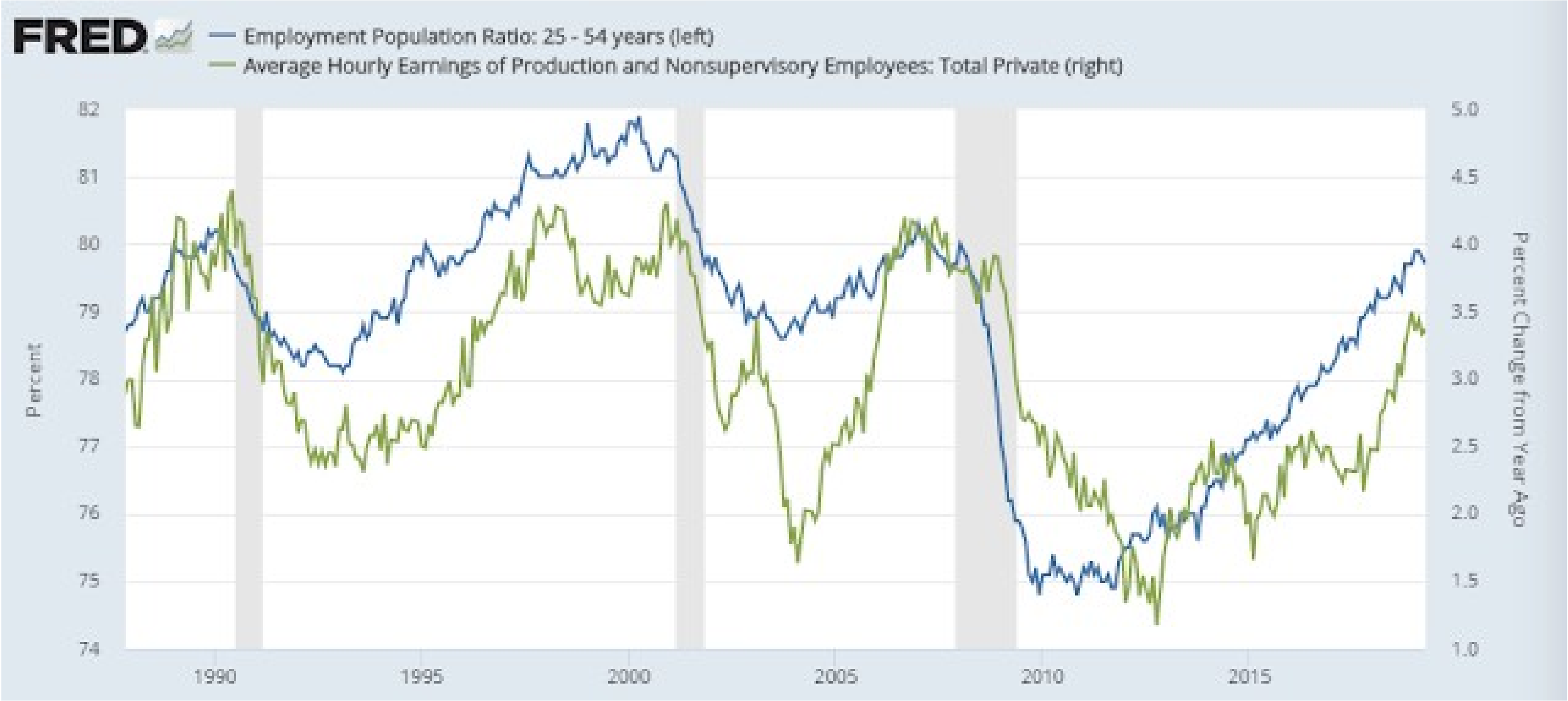
Expected profit share

Short-term Phillips curve

$$\frac{\dot{\mathbf{w}}}{\mathbf{w}} := \phi(\lambda) + \gamma\frac{\dot{p}}{p},$$

$$i := i(\omega) := \frac{\dot{p}}{p} = \eta_p(\mu\omega - 1).$$

Inflation



$$I := \frac{\kappa(\pi_e)}{\nu(\omega)} K,$$ Aggregate investment

$$C := c_h(\omega + r d_f + \Delta \pi_e) Y.$$ Aggregate consumption

$$a := \frac{Y}{L} \qquad a(\omega(t)) = A e^{\alpha t} \left(\frac{\sigma \omega(t)}{1-b} \right)^{\frac{1}{\eta}} \cdot$$ Labour productivity

$$g := g(\omega, \lambda, d_f) := \hat{Y} = \frac{\kappa(\pi_e)}{\nu(\omega)} - \delta - \frac{\dot{\omega}}{(1-\sigma\omega)\eta}.$$ Real growth rate

Oligopoly Pricing

$$\max_{Y \geq 0} p(Y)Y - c(Y),$$

Profit maximisation

$$c'(Y^*) = w\partial L/\partial Y,$$

First-order condition if price-taker

$$p'(Y^*)Y^* + p(Y^*) = c'(Y^*).$$

FOC if price-maker

$$p(Y^*) > c'(Y^*).$$

$$c(Y^*)/Y^* = wL^*/Y^* = \omega^*$$

Average cost

$$p = \sigma \mathbf{w} \frac{\partial L}{\partial Y},$$

Oligopolistic FOC

Causality chain at time t:

Capital stock -> oligopolistic profit max -> Employment

-> real wages -> nominal wages

-> inflation rate and wage change

->consumption and investment

->t+1

No climate feedback loop

Bovari, Giraud & McIsaac (2017)

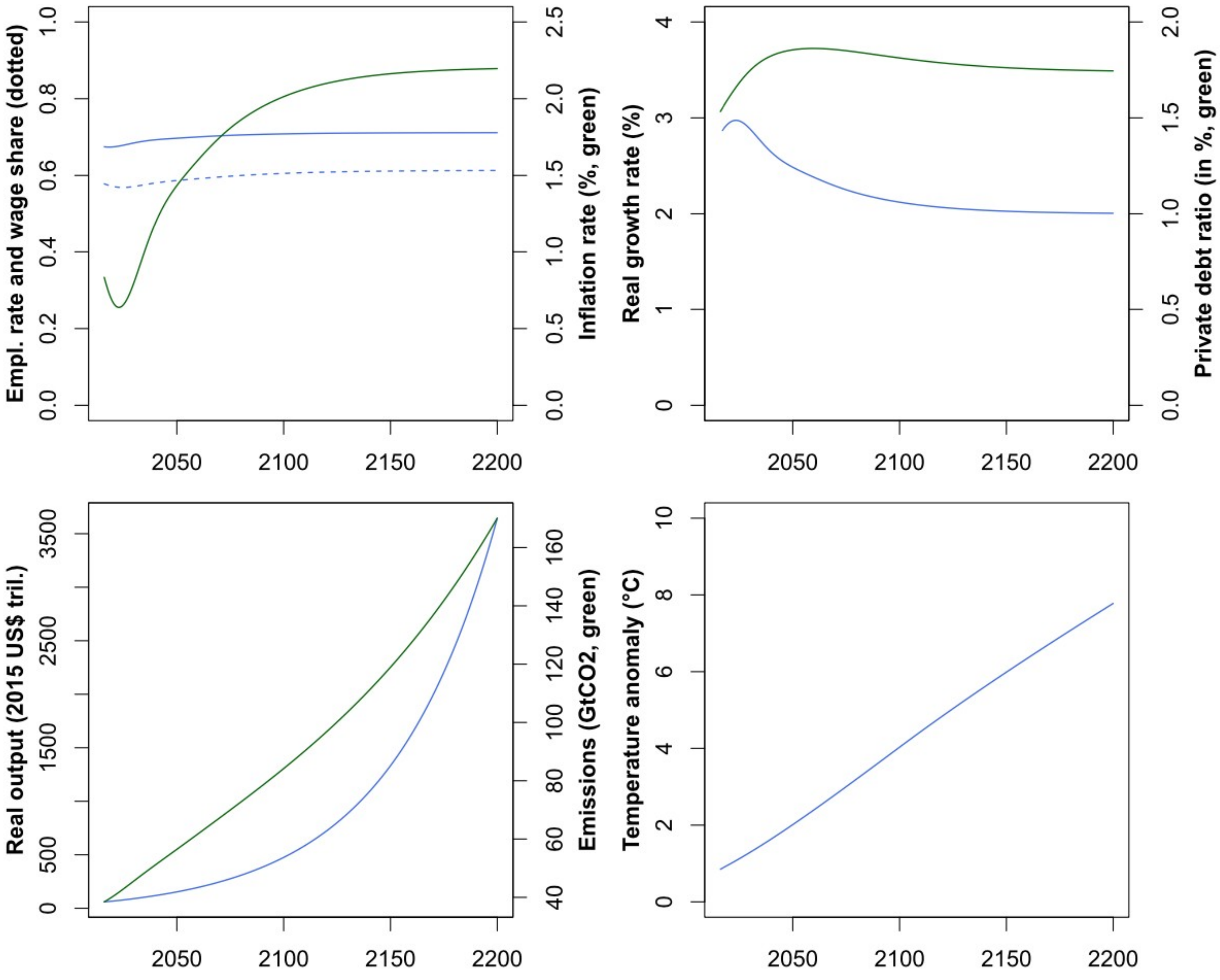


Fig. 1. Trajectories of the main simulation variables in the *No feedback loop scenario*.

Bovari, Giraud, McIsaac (2017)

The Dietz-Stern Scenario

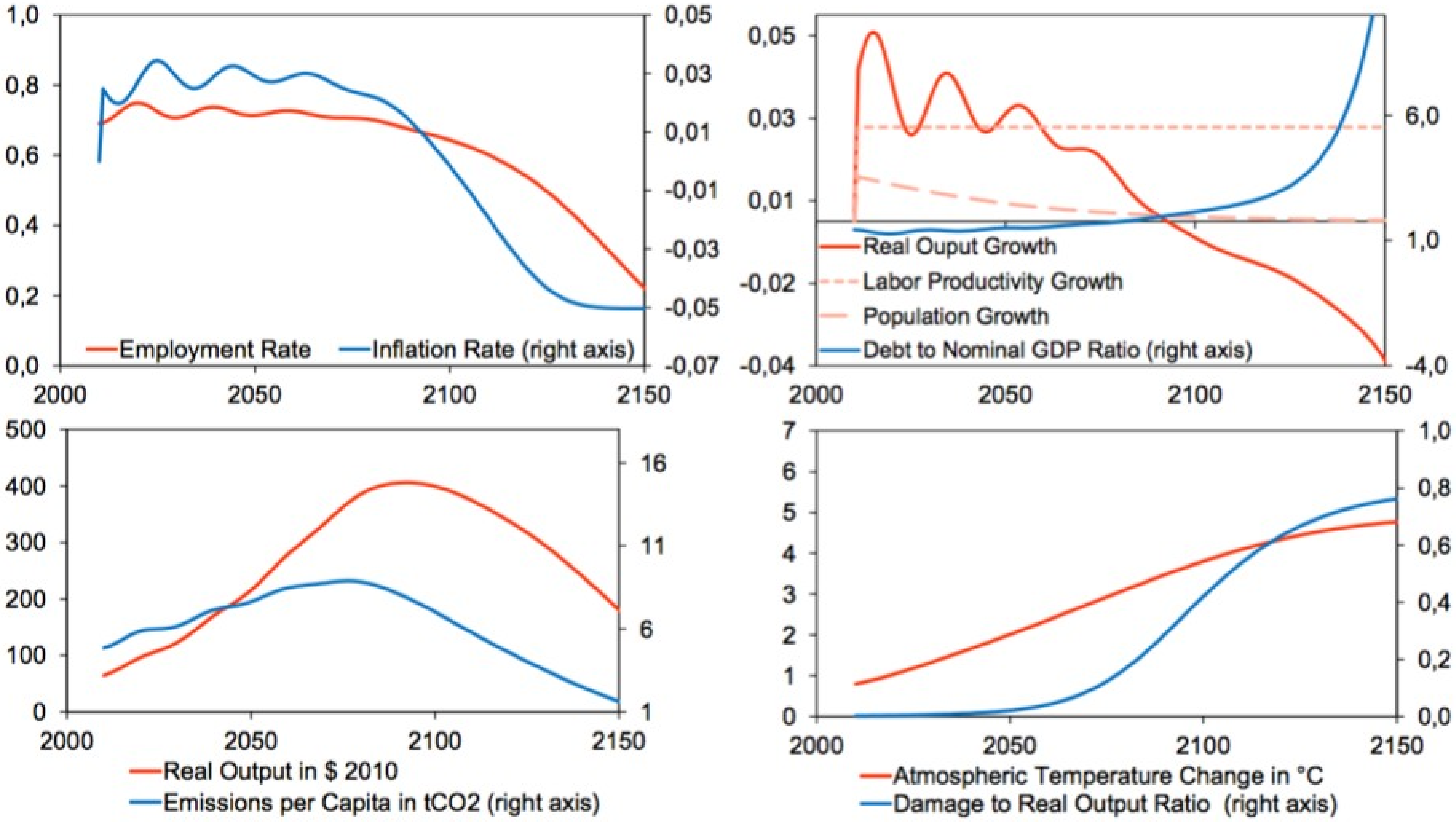
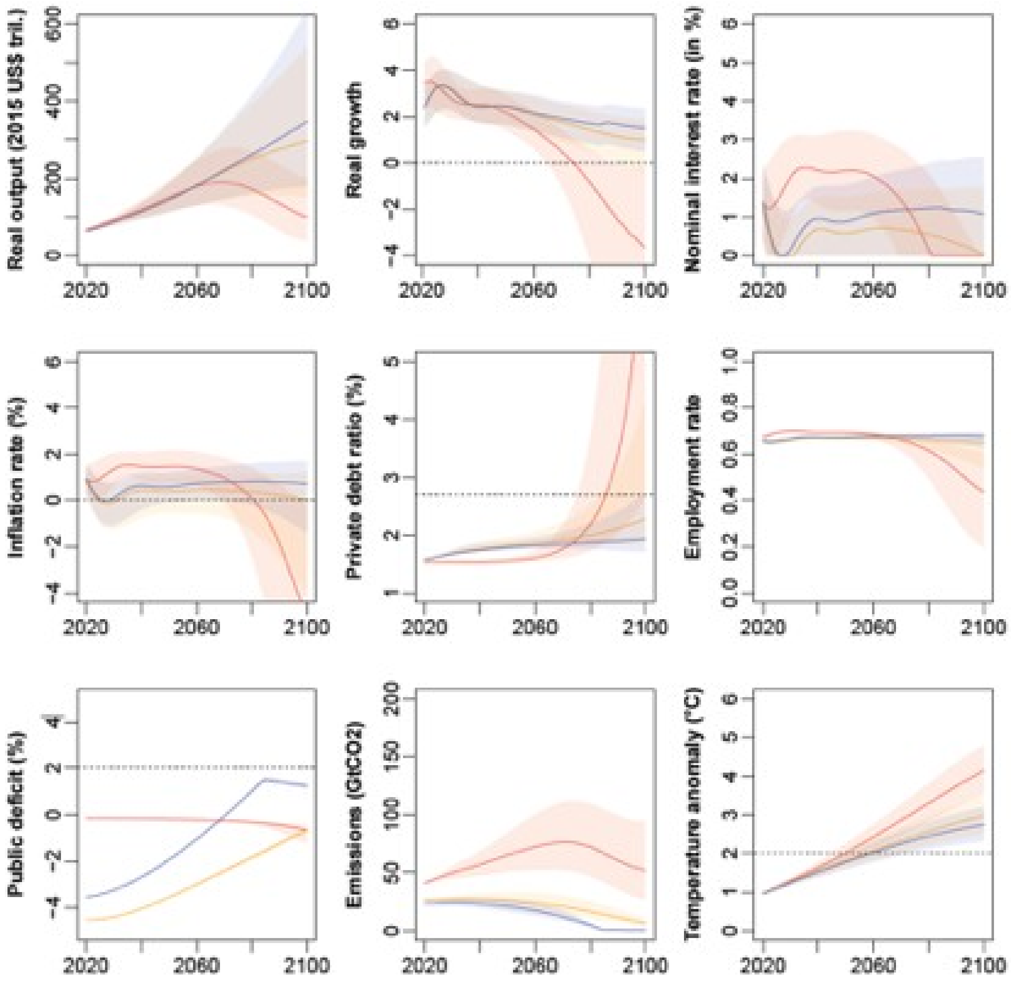
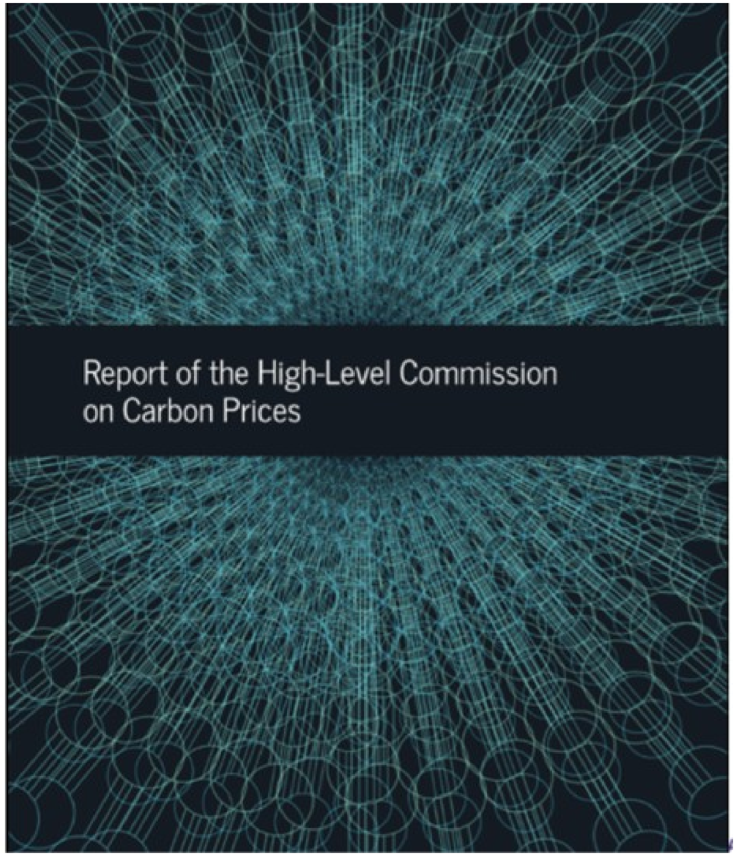


Figure: Trajectories of the main simulation outputs in the Dietz-Stern case.

A stochastic version: climate sensitivity, ocean absorption, labour productivity

Stern-Stiglitz Report on Carbon Pricing (2018)





Coupling with iLoveclim

Roche (2013)

Roche et al. (2014)

Bouttes et al. (2015)

Bügelmayer et al. (2015)

Kitover et al. (2015)

Quiquet et al. (2018)

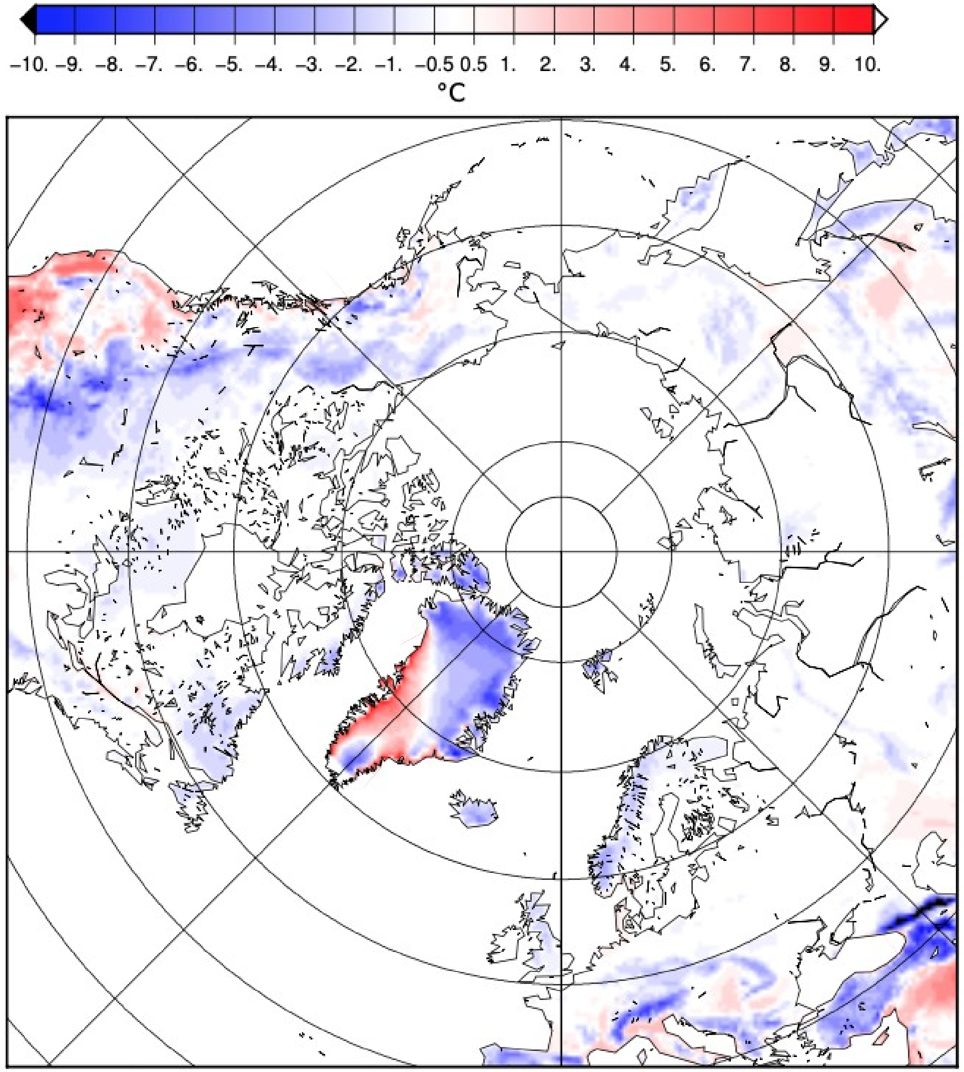
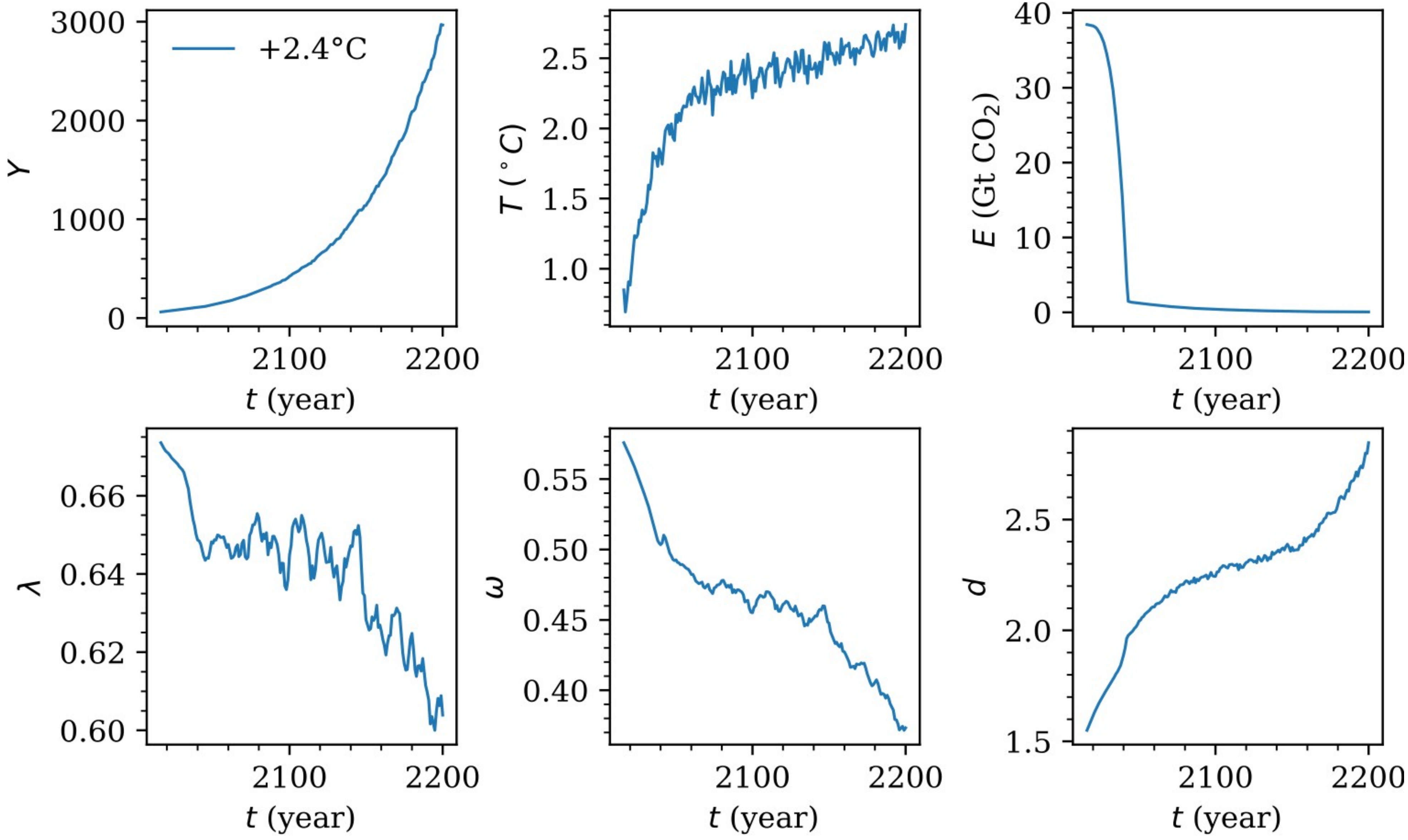


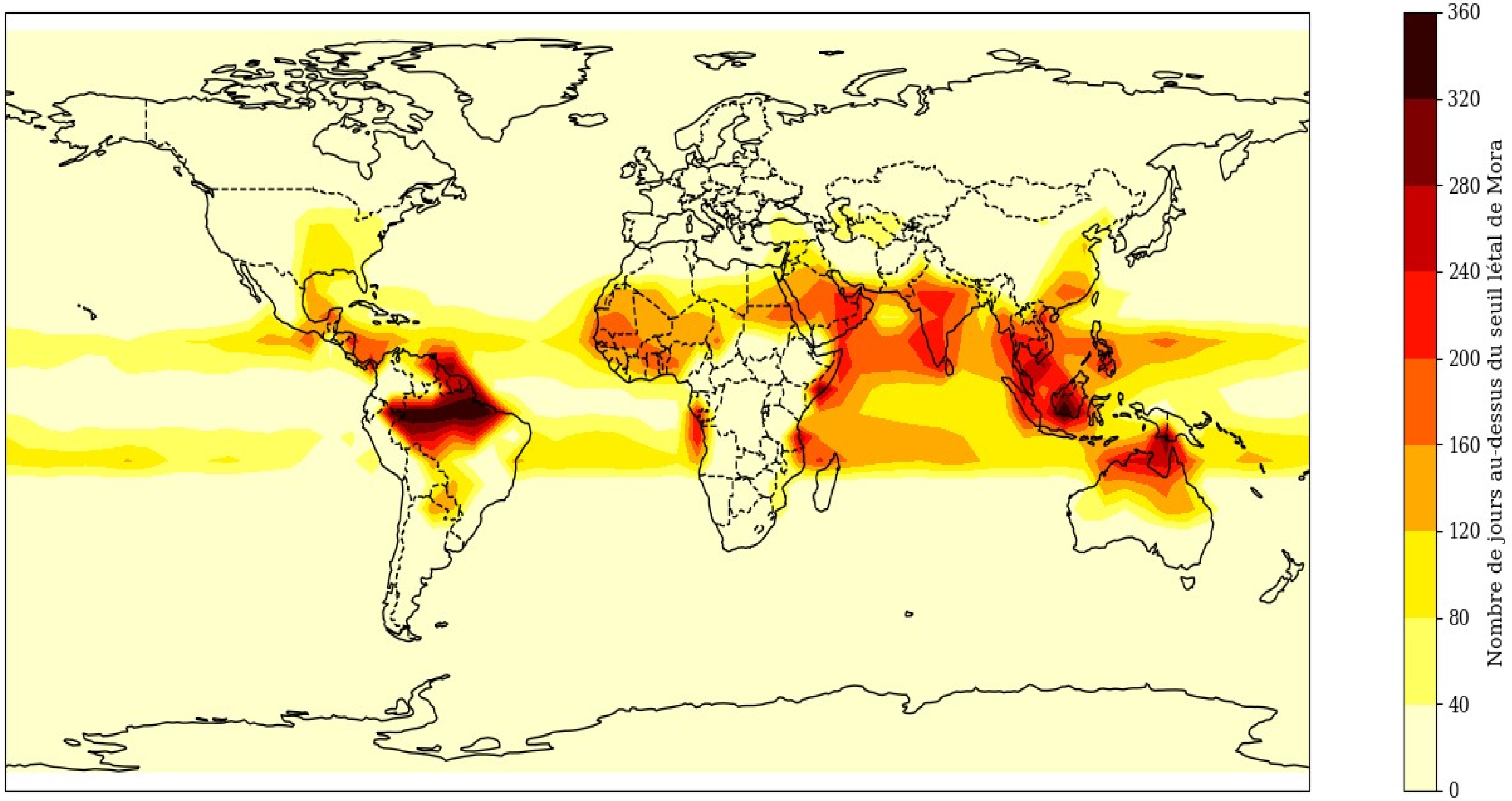
Figure 6. Annual mean temperature anomaly due to the downscaling procedure, in degrees, computed as the difference between the downscaled temperature and the interpolated temperature fields. This is one example taken from one particular year.

EXAMPLE: A BASIC SCENARIO : RCP 4.5 + COPING-iLoveclim

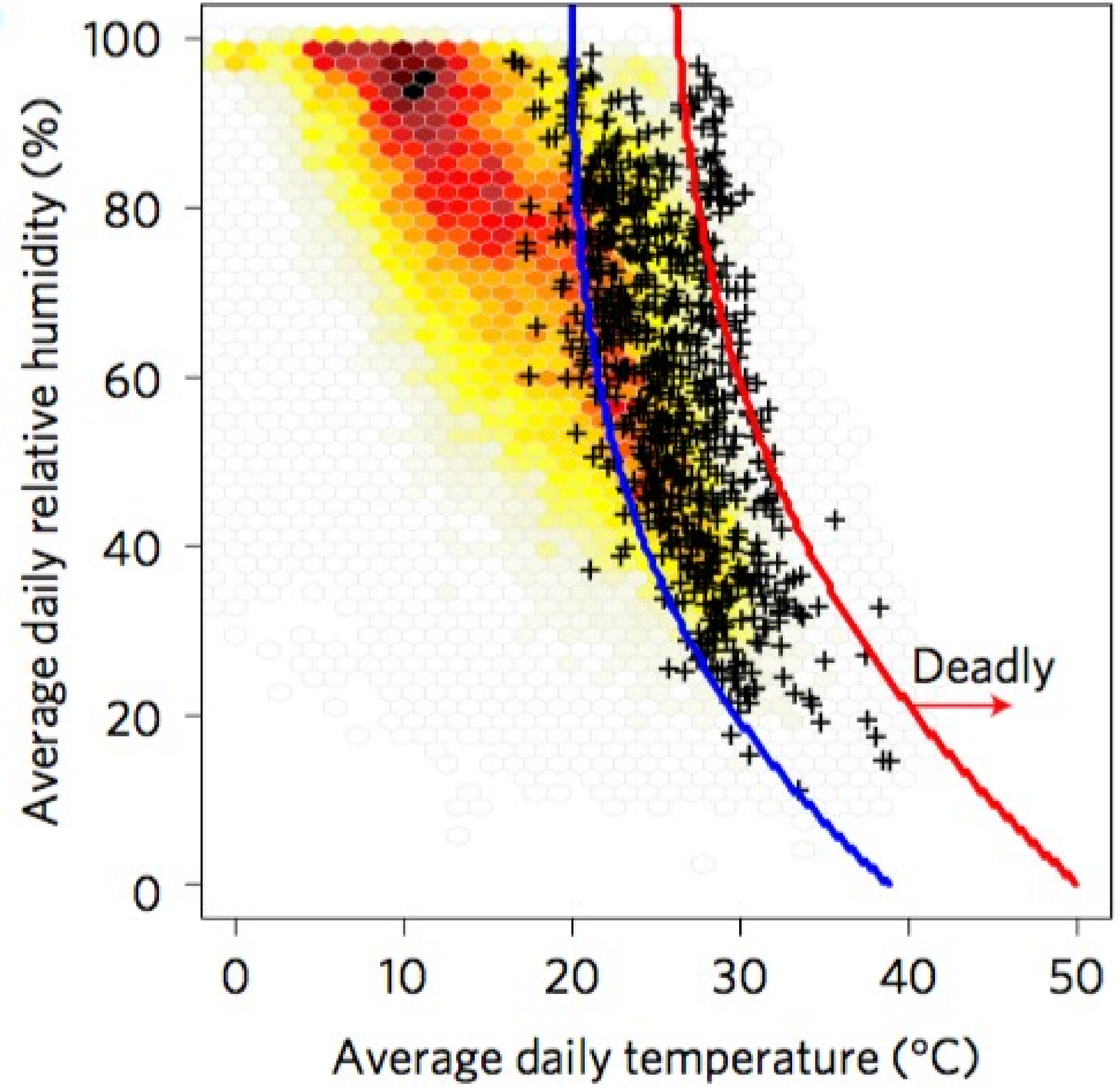


Climate sensitivity: 3.9

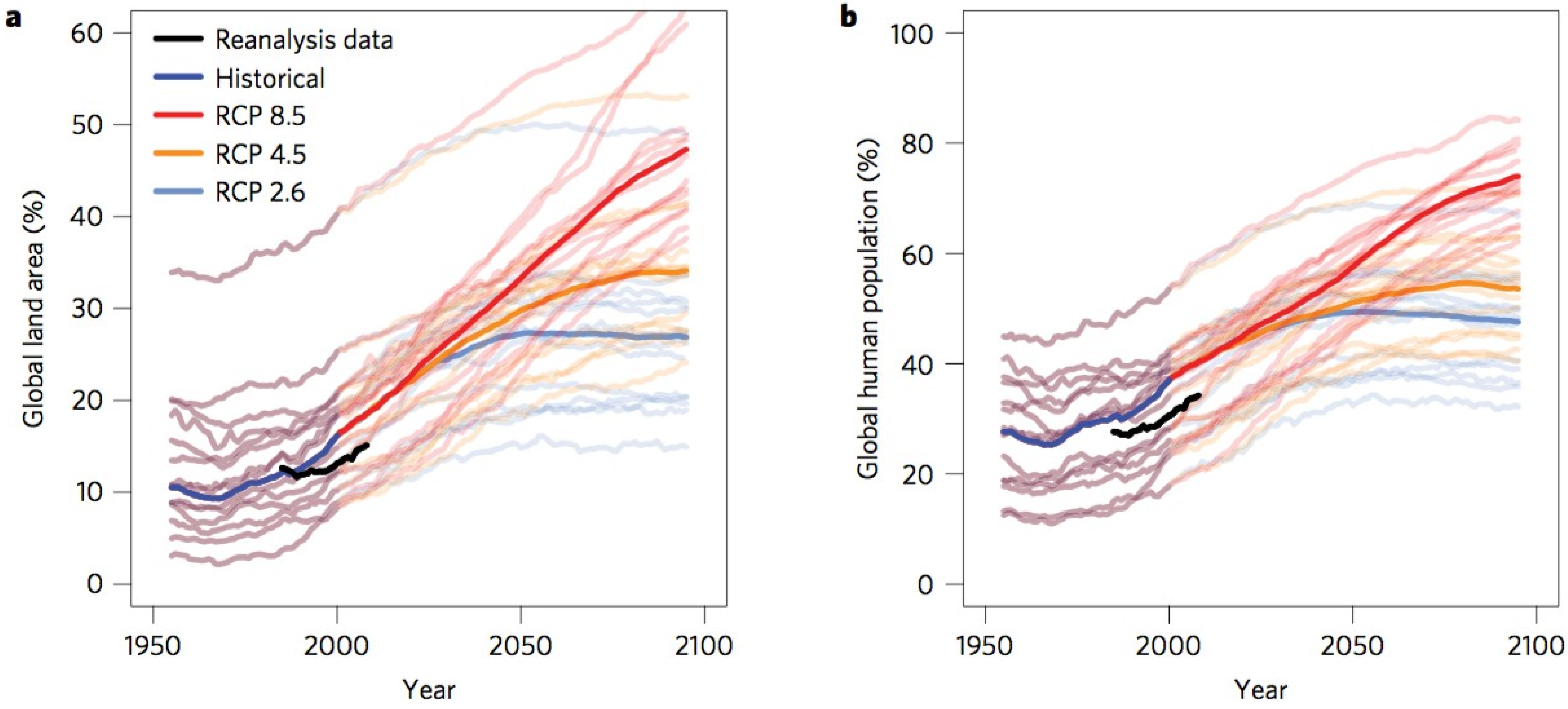
Peaks of heat-humidity might make part of the world uninhabitable



1. ECOLOGICAL POLYCRISIS

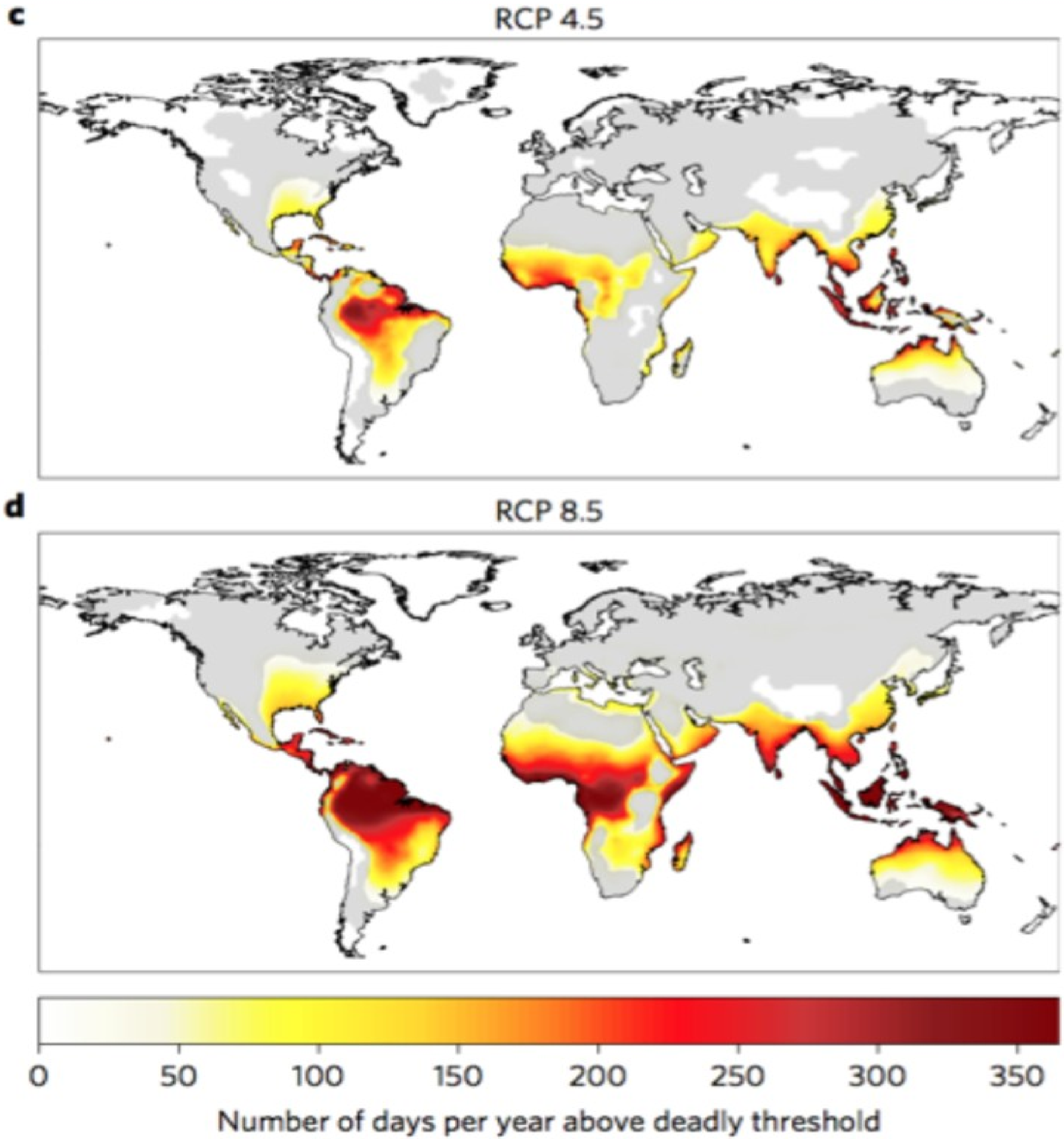


Average daily relative humidity (%)
Average daily temperature (°C)
Deadly
0
20
40
60
80
100
0
10
20
30
40
50



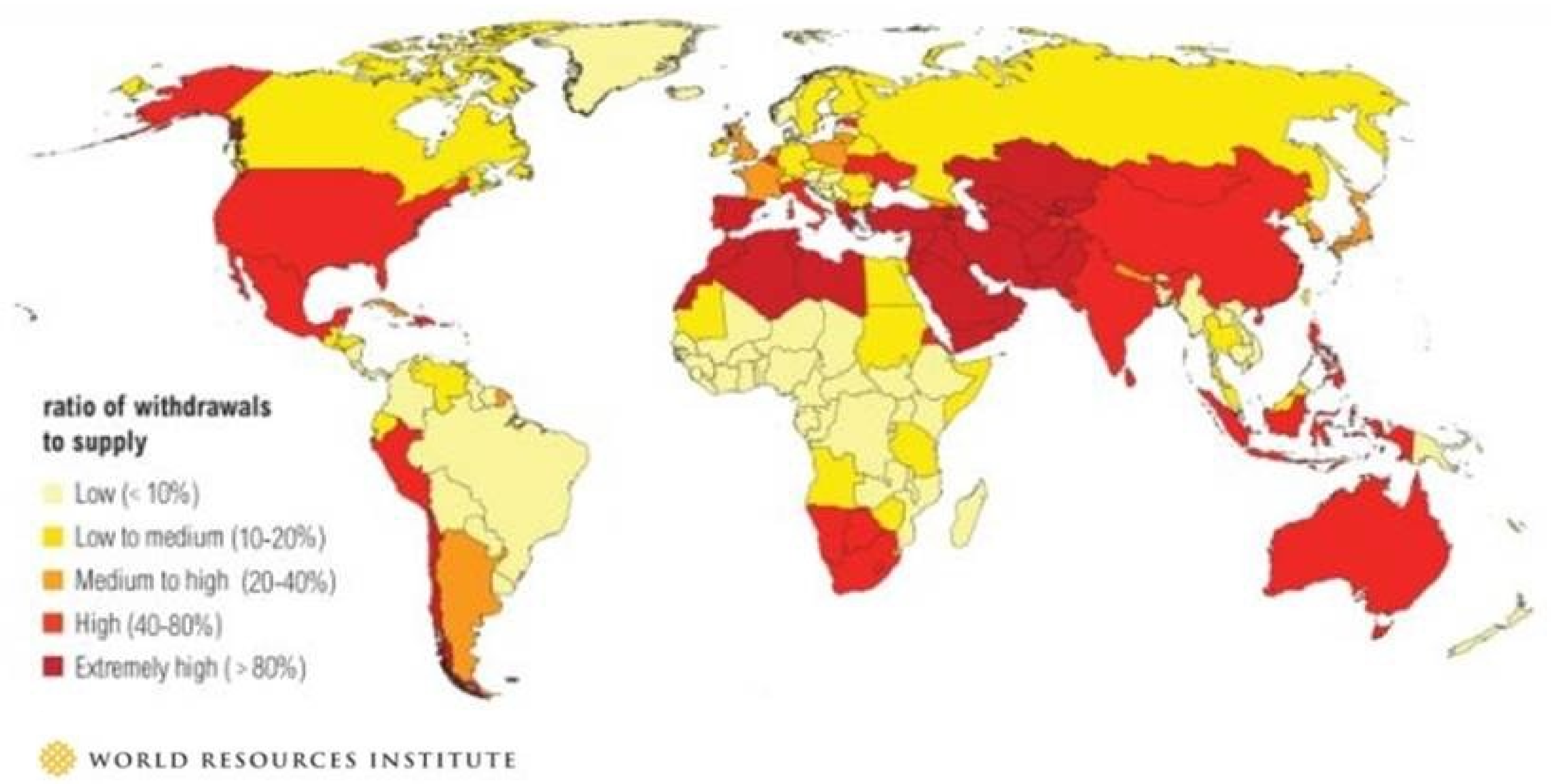
a
Reanalysis data
Historical
RCP 8.5
RCP 4.5
RCP 2.6
Global land area (%)
0
10
20
30
40
50
60
1950
2000
2050
2100
Year
b
Global human population (%)
0
20
40
60
80
100
1950
2000
2050
2100
Year

Average number of days per y with deadly heat-humidity in 2100.



Lack of drinkable water

Hydro stress 2040



The growing scarcity of minerals…

Giraud et al. (2017, 2019)

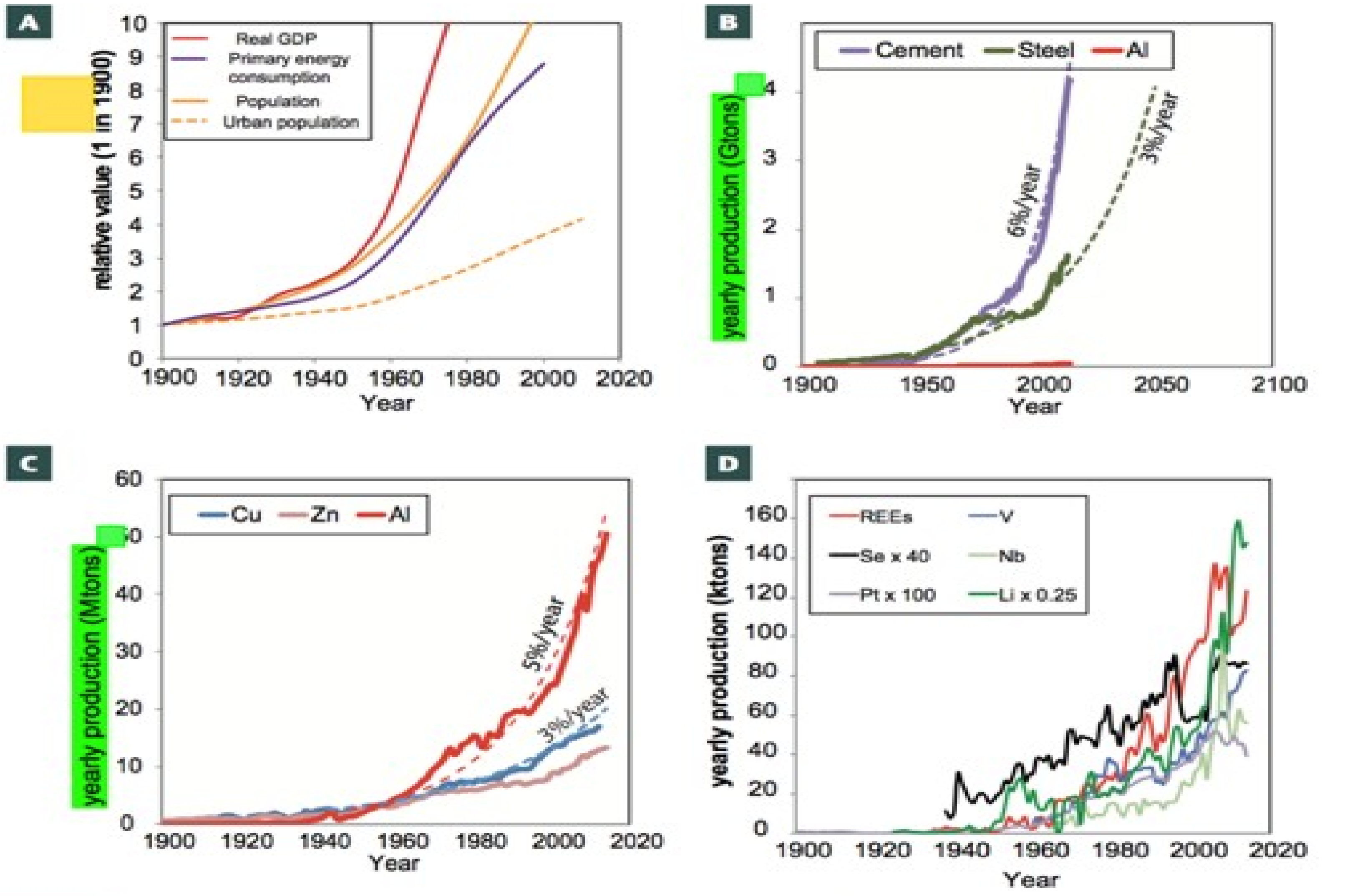
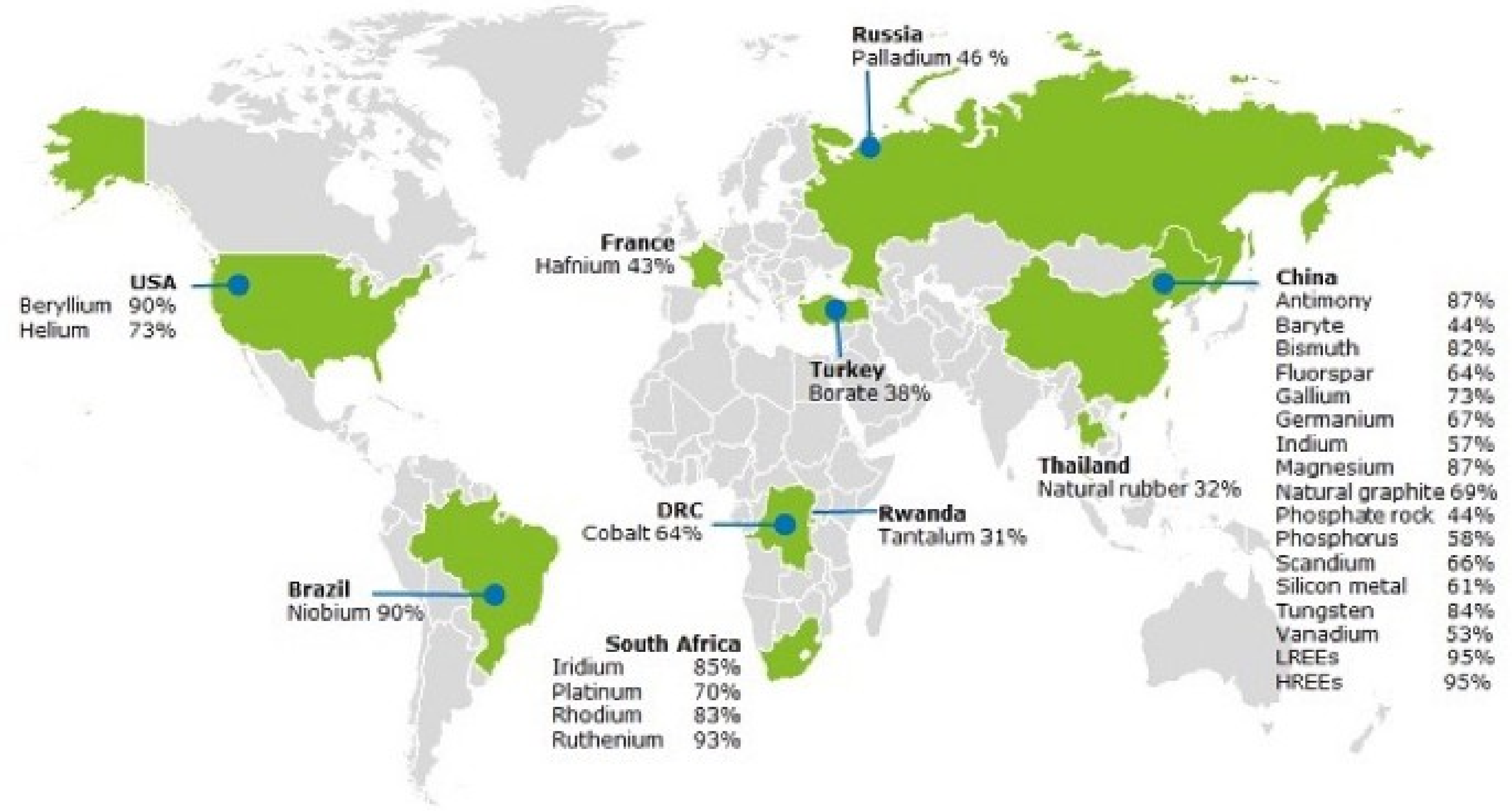


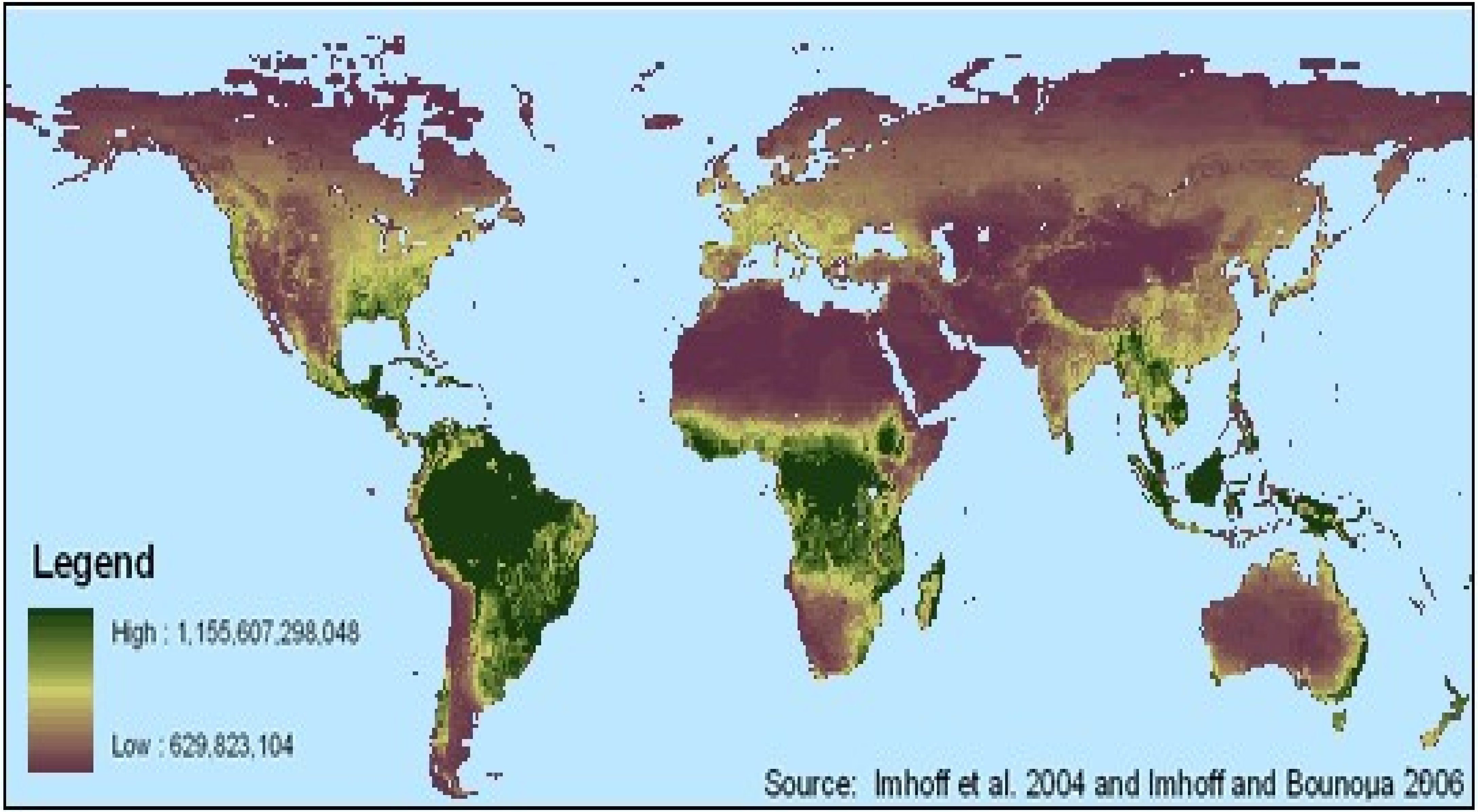
FIGURE 1 (**A**) Historical evolution of various indicators of prosperity and human activity. FROM STEFFEN ET AL. (2014). (**B**) Yearly production, between 1900 and 2015 of cement, steel and Al. (**C**) Yearly production, between 1900 and 2015 of Cu, Zn and Al. (**D**) Yearly production of rare-earth elements (REEs), V, Se, Nb, Pt and Li. The dashed lines in (B–C) show the evolution of production calculated for the indicated growth rates. DATA IN PARTS 1B, 1C AND 1D FROM USGS (2017b).

The (geopolitical) mineral Challenge



European Commission,

Regional NPP (I)



Regional HANPP (II)

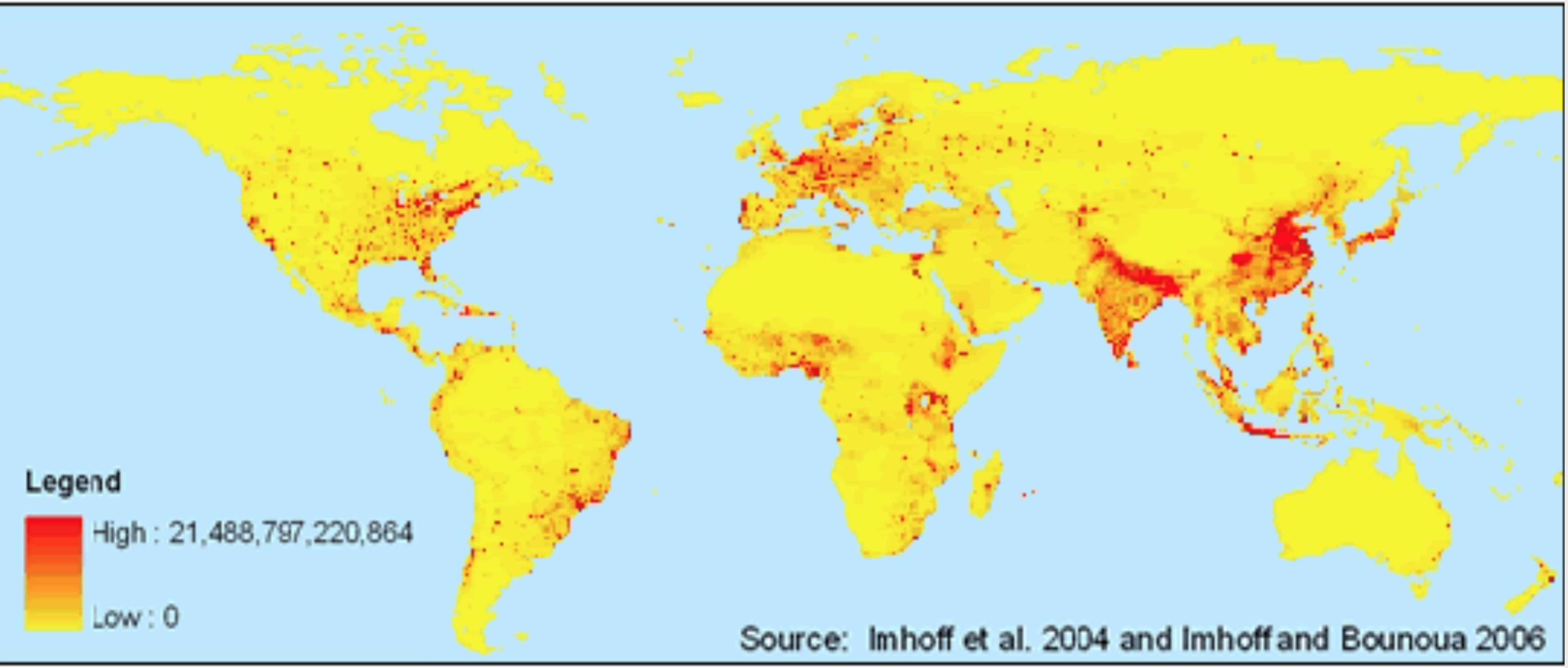


Figure 2. Human Appropriation of Net Primary Productivity (HANPP) (in grams of carbon)

Regional deficit in biomass

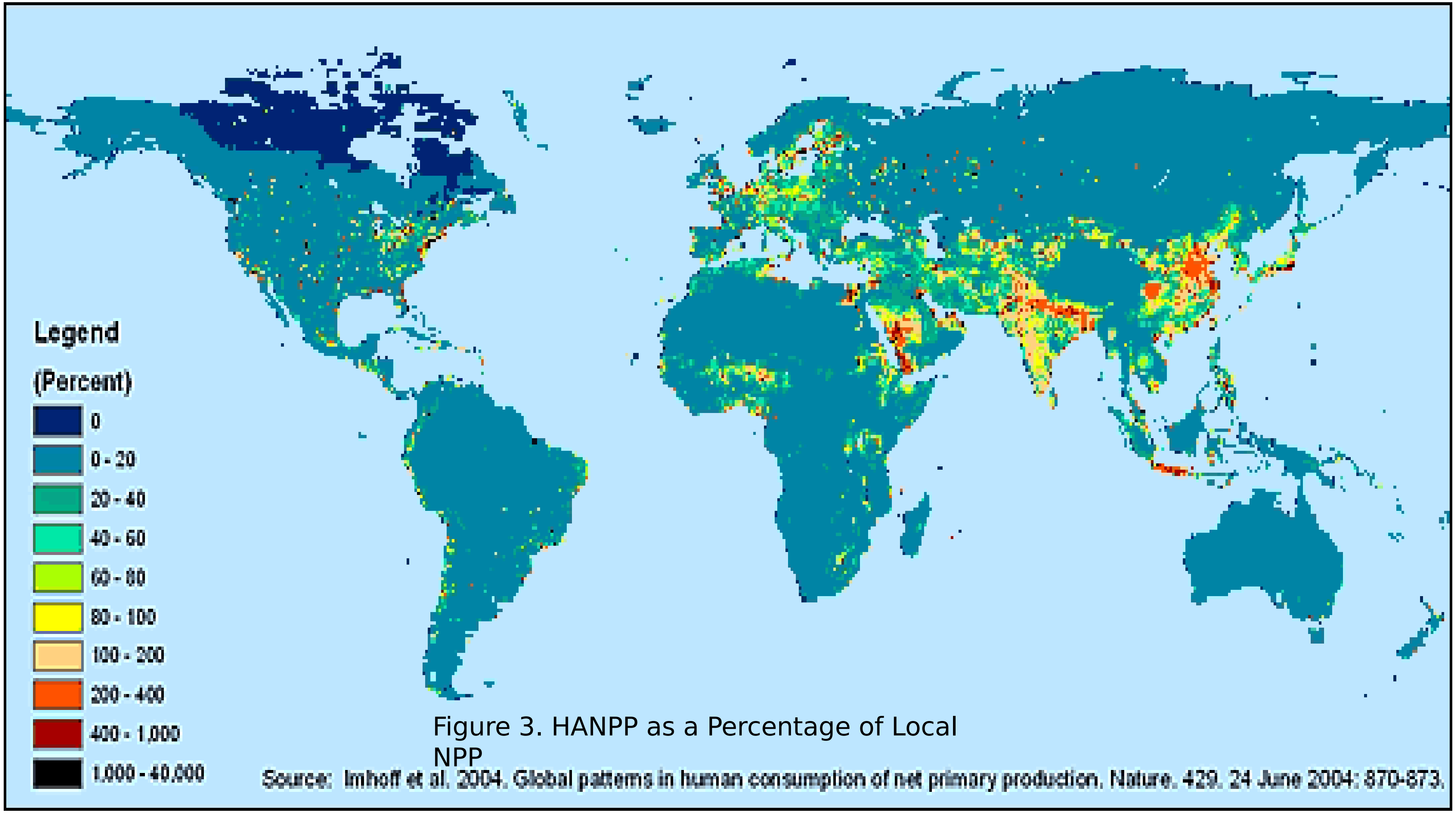
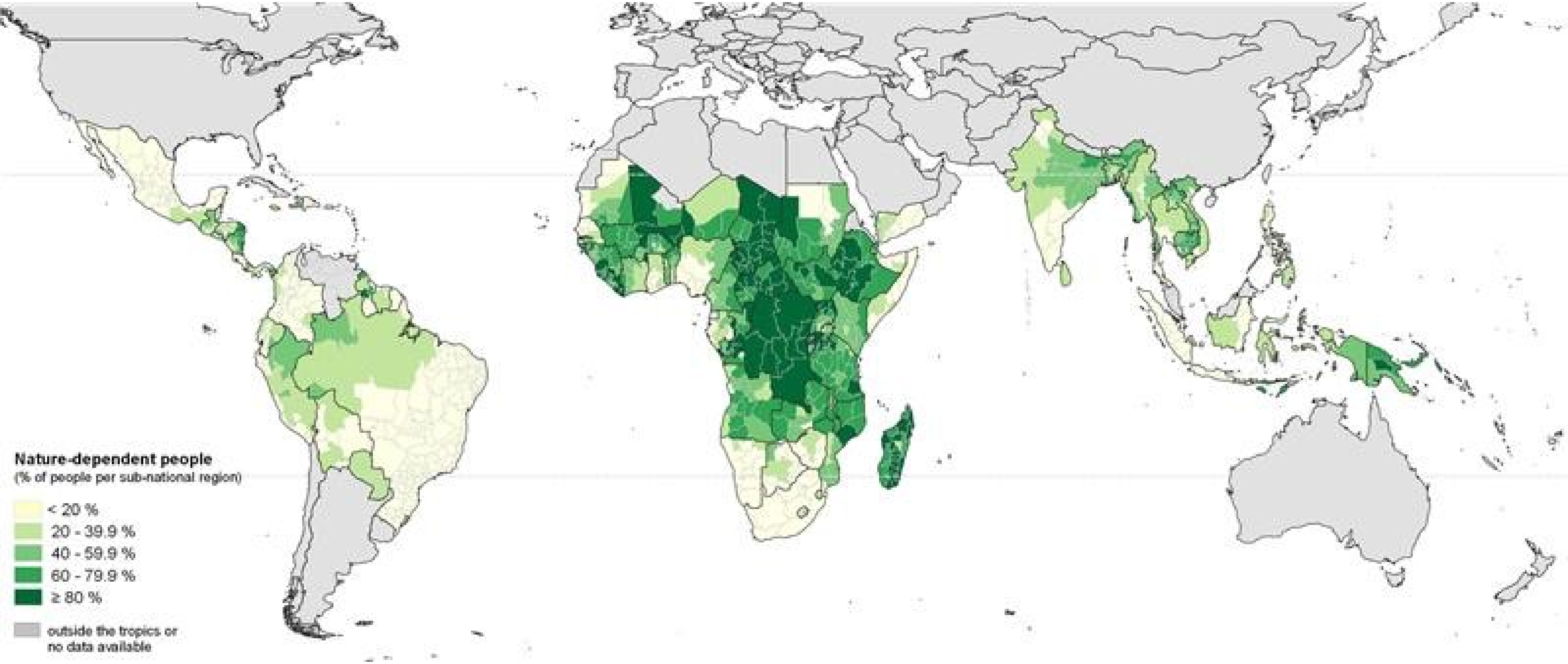


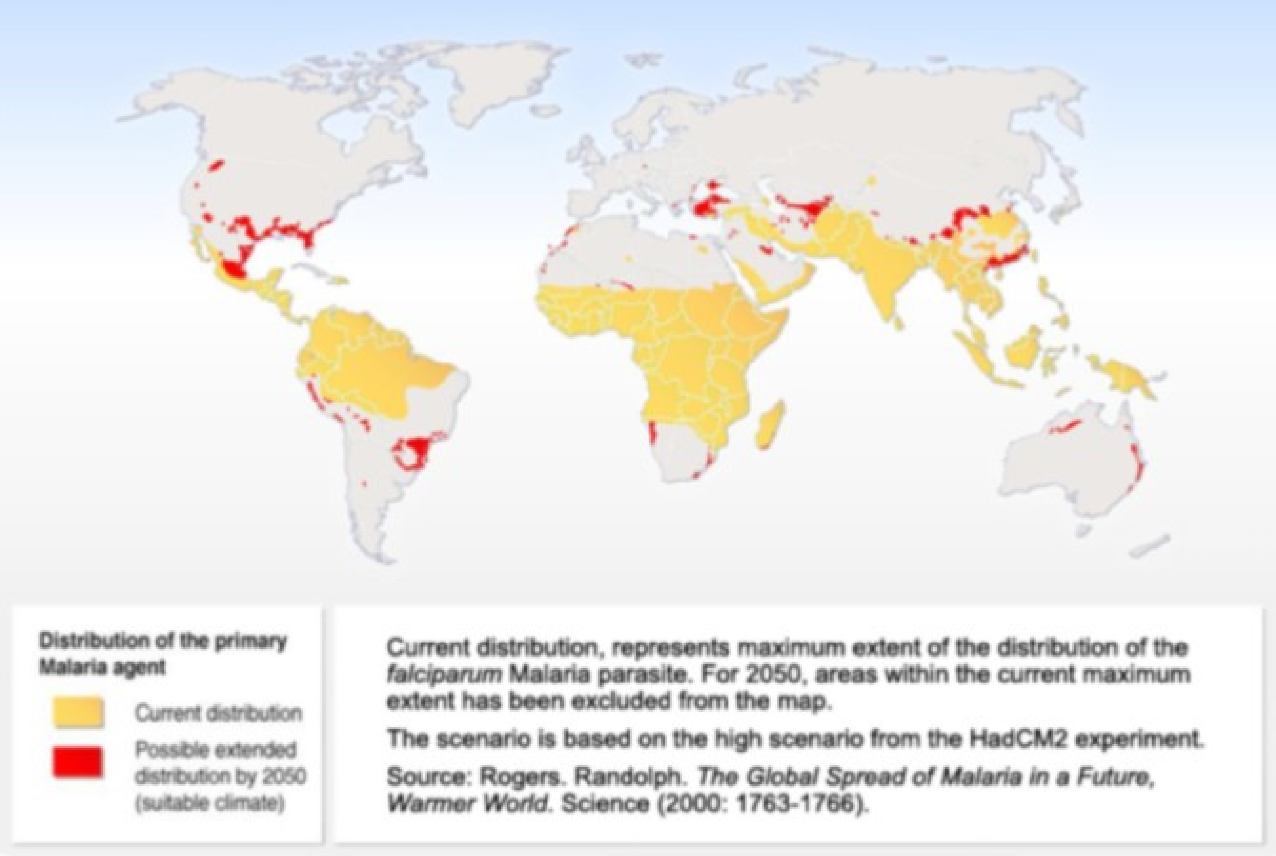
Figure 3. HANPP as a Percentage of Local NPP

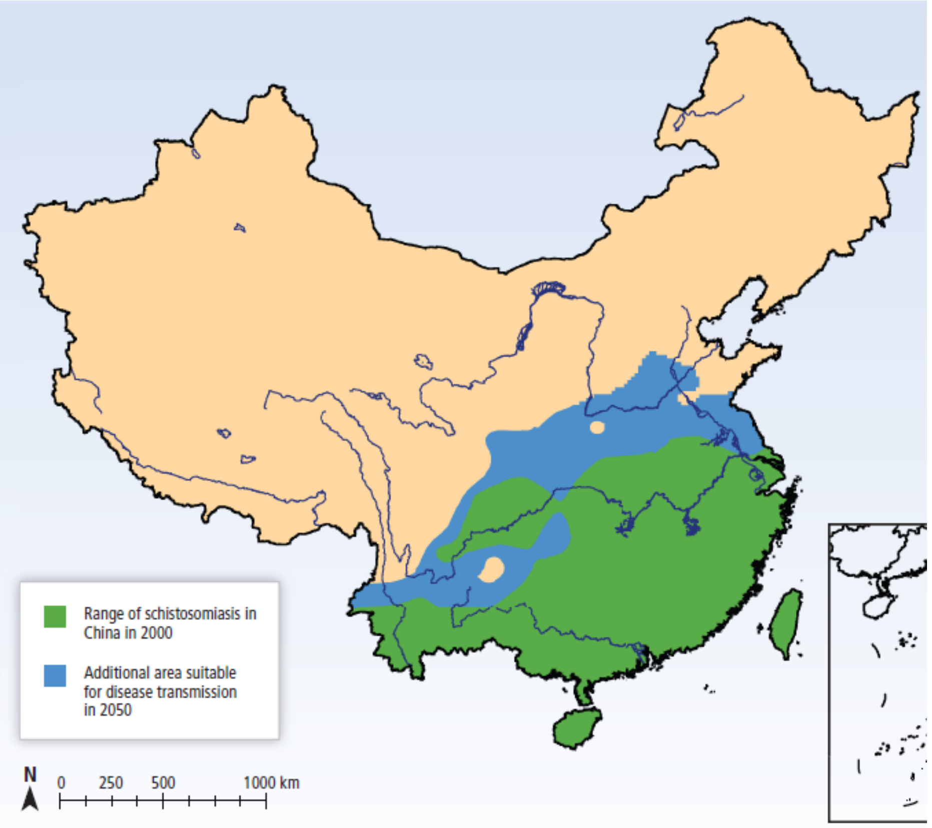


https://www.sciencedirect.com/science/article/pii/S0959378021001473?via%3Dihub

Growing areas of disease/parasite prevalence

Extension of malaria areas in 2050





Effect of temperature increase on the extension of Schistosomiasis japonica (parasite) transmission areas
(Modeling, with +1.6°C in China in 2050) (IPCC 2013, Fig.11.4)

GEJP

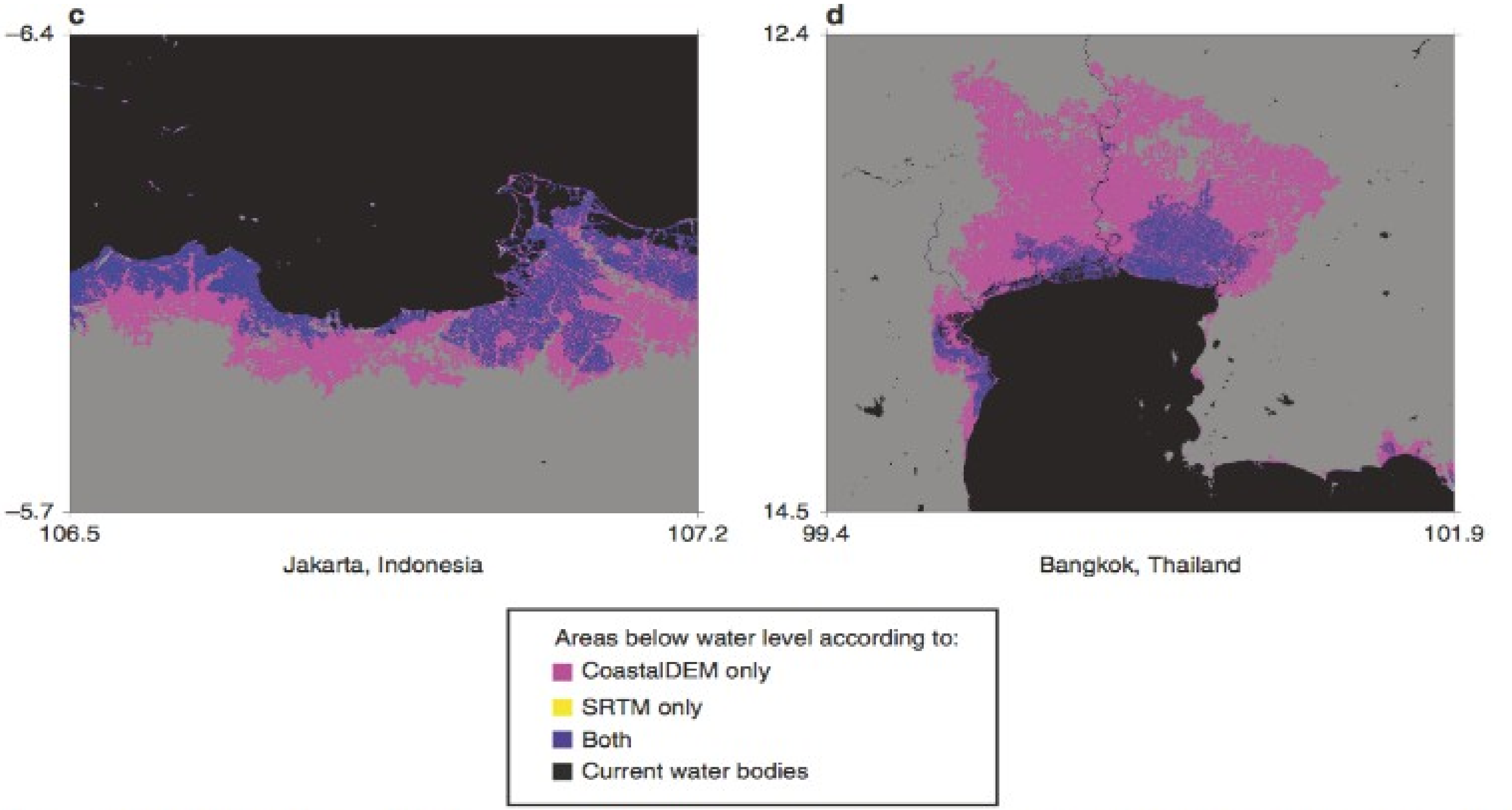
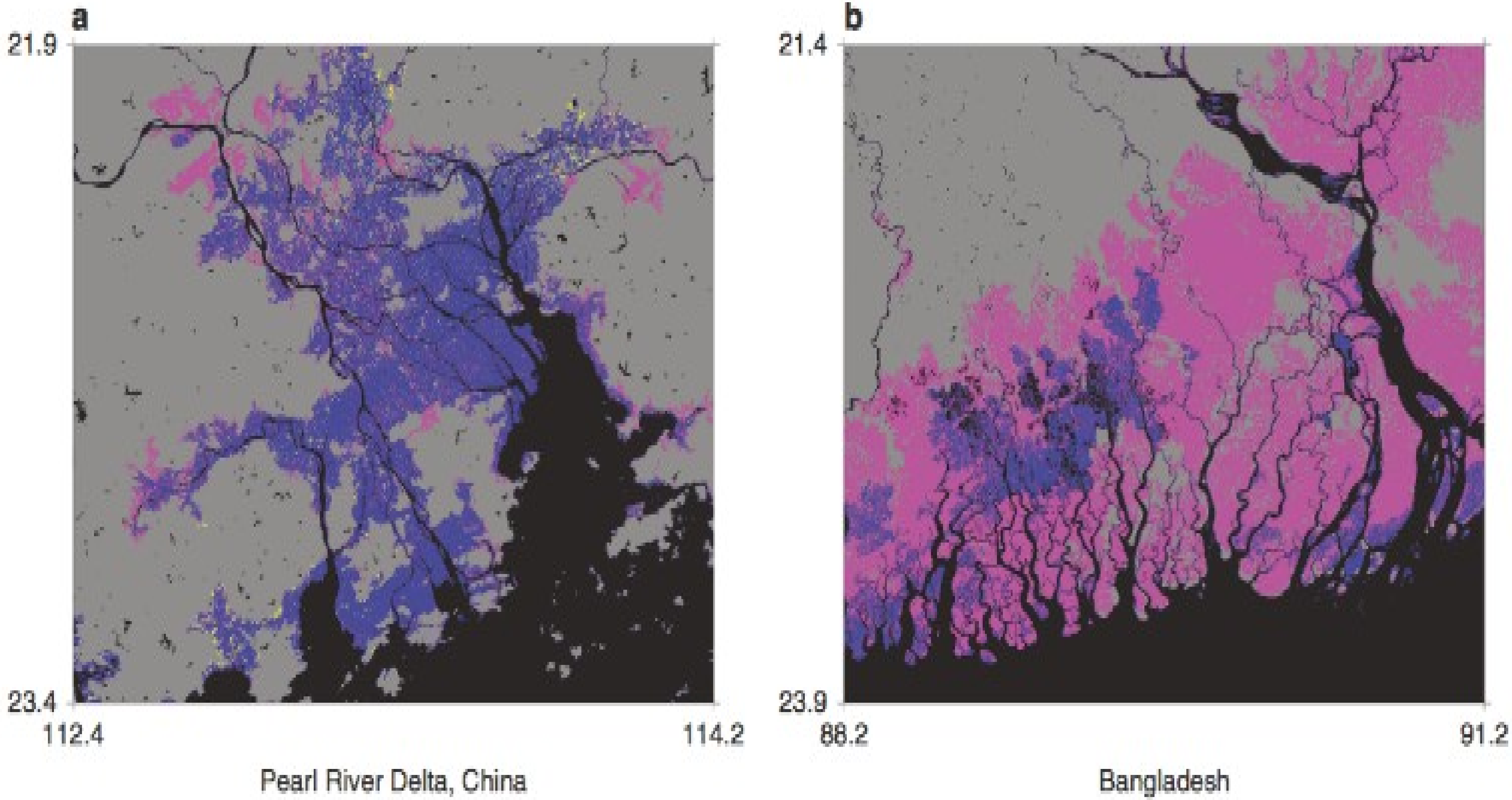


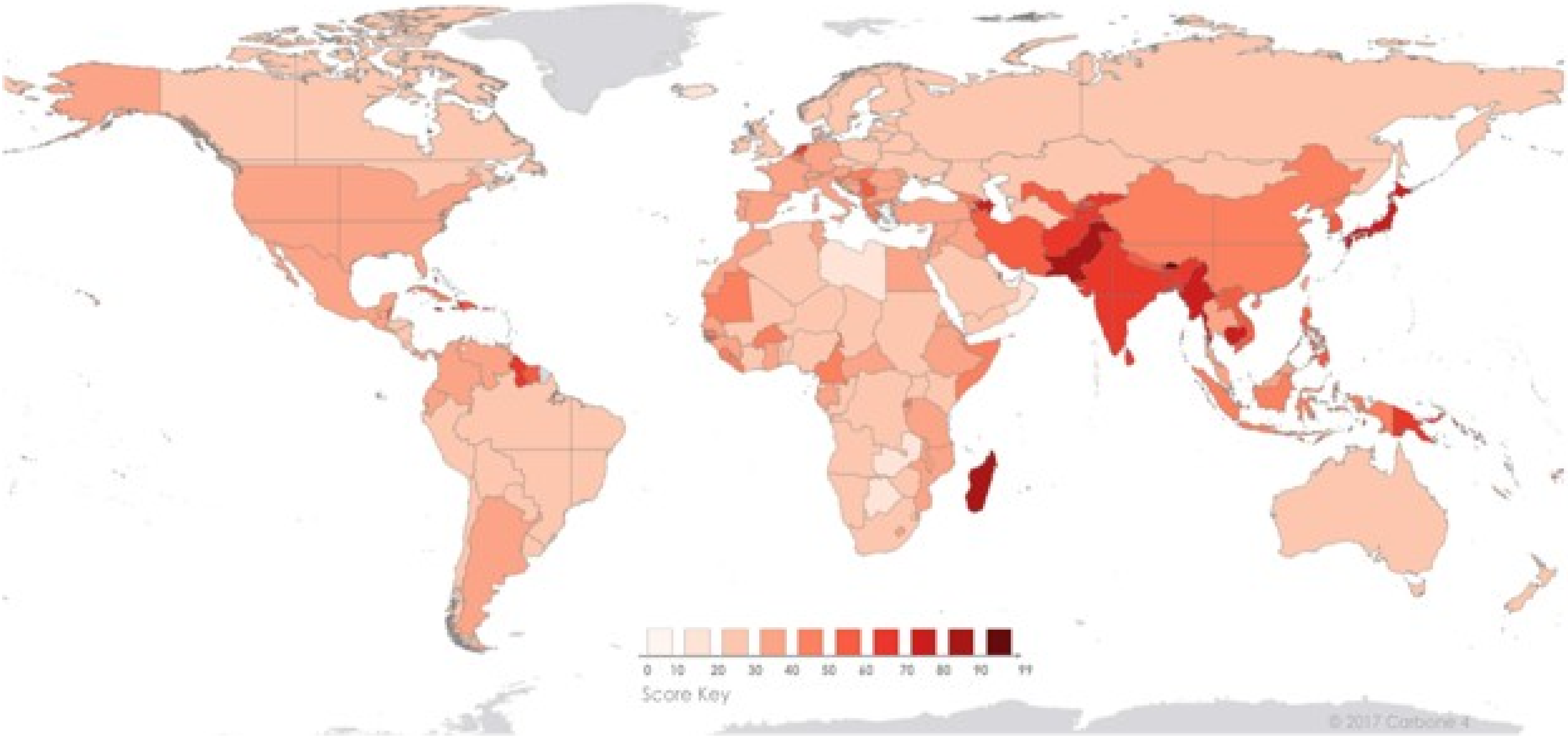
Fig. 1 Permanent inundation surfaces predicted by CoastalDEM and SRTM given the median K17/RCP 8.5/2100 sea-level projection. Locations include (**a**) the Pearl River Delta, China; (**b**) Bangladesh; (**c**) Jakarta, Indonesia; and (**d**) Bangkok, Thailand. Low-lying areas isolated from the ocean are removed from the inundation surface using connected components analysis. Current water bodies are derived from the SRTM Water Body Dataset. Gray areas represent dry land. Axis labels denote latitude and longitude


a
21.9
23.4
112.4
114.2
Pearl River Delta, China
b
21.4
23.9
88.2
91.2
Bangladesh

1. ECOLOGICAL POLYCRISIS
2. COSTS are DIFFICULT to ASSESS

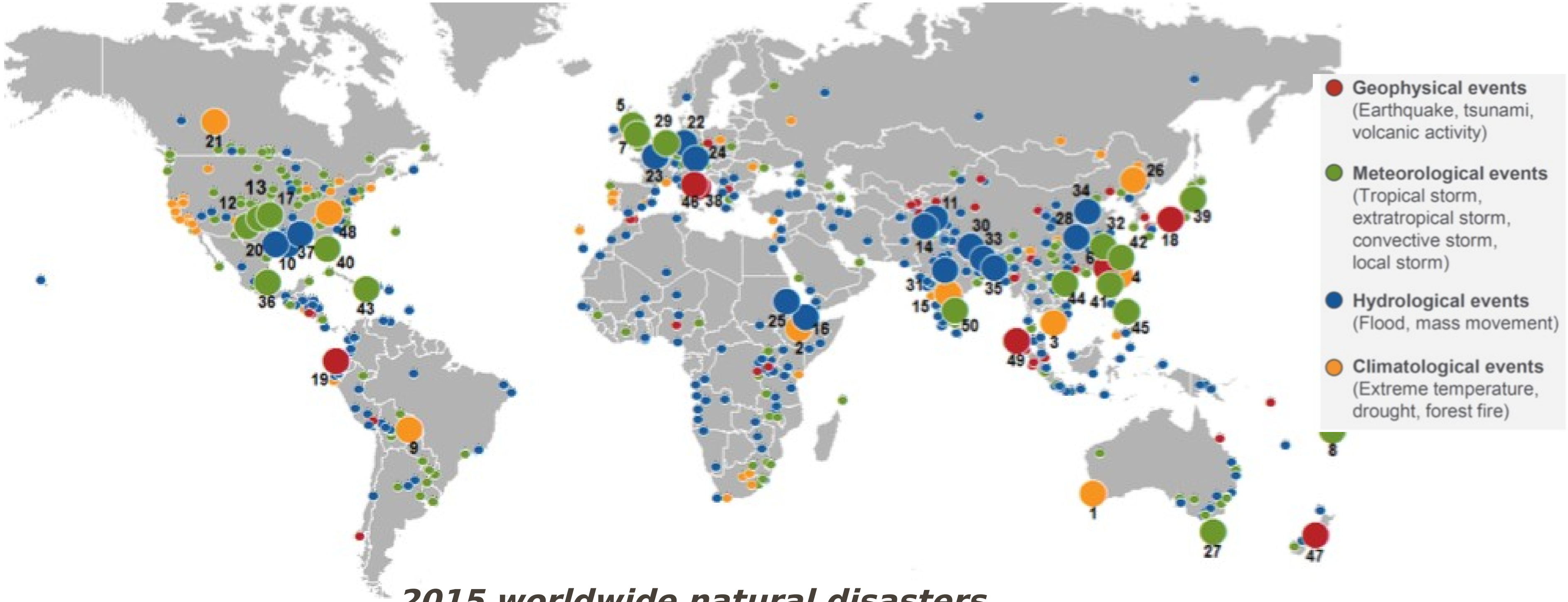
CRIS sovereign analyses

- The countries most at risk account for 11% of the world economy and 28% of global population.
- These countries are particularly exposed and vulnerable to the intensification of flooding, sea level rise and storms.



•Climate change impacts have significant economic 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.**



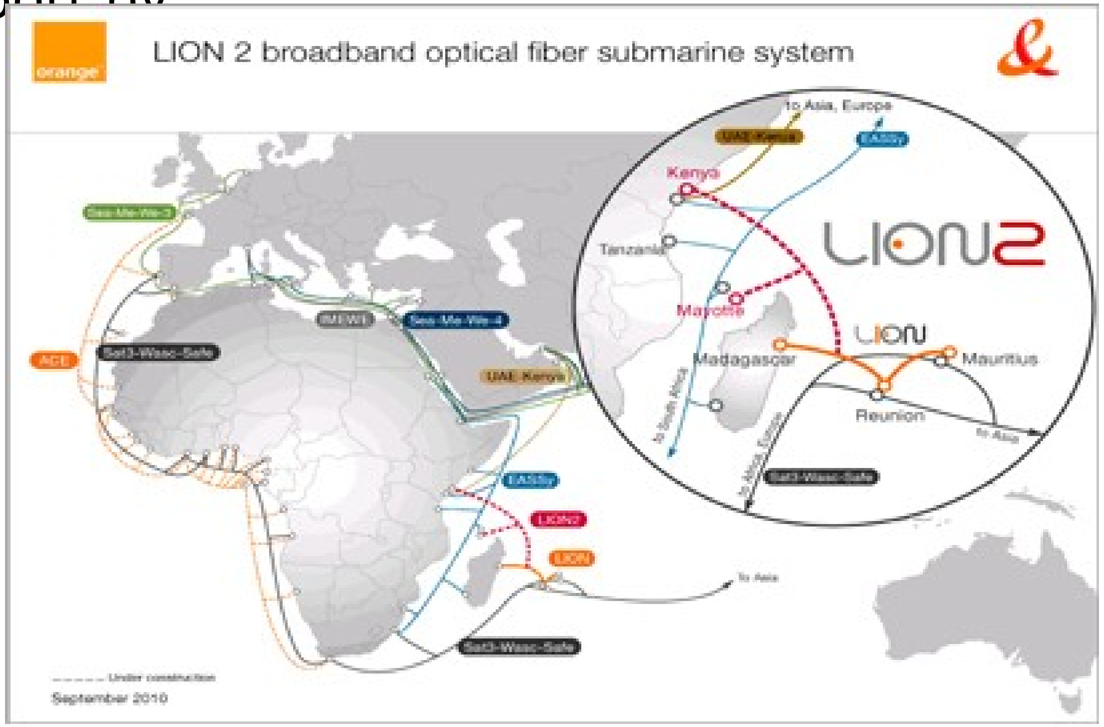
2015 worldwide natural disasters
Source : Munich Re 2016

Significant risks to infrastructures

Potential inundation of Dzaoudzi–Pamandzi airport by 0.5 – 3.5 m

Threat of waves up to 5 m high at Mamoudzou

Risk of damage to LION 2 submarine cable



Impacts intensify with subsidence, sea-level rise, loss

Climate damage as a percentage of real GDP

Damage functions

Nordhaus (2013)

Dietz and Stern (2015)

Weitzman (2021)

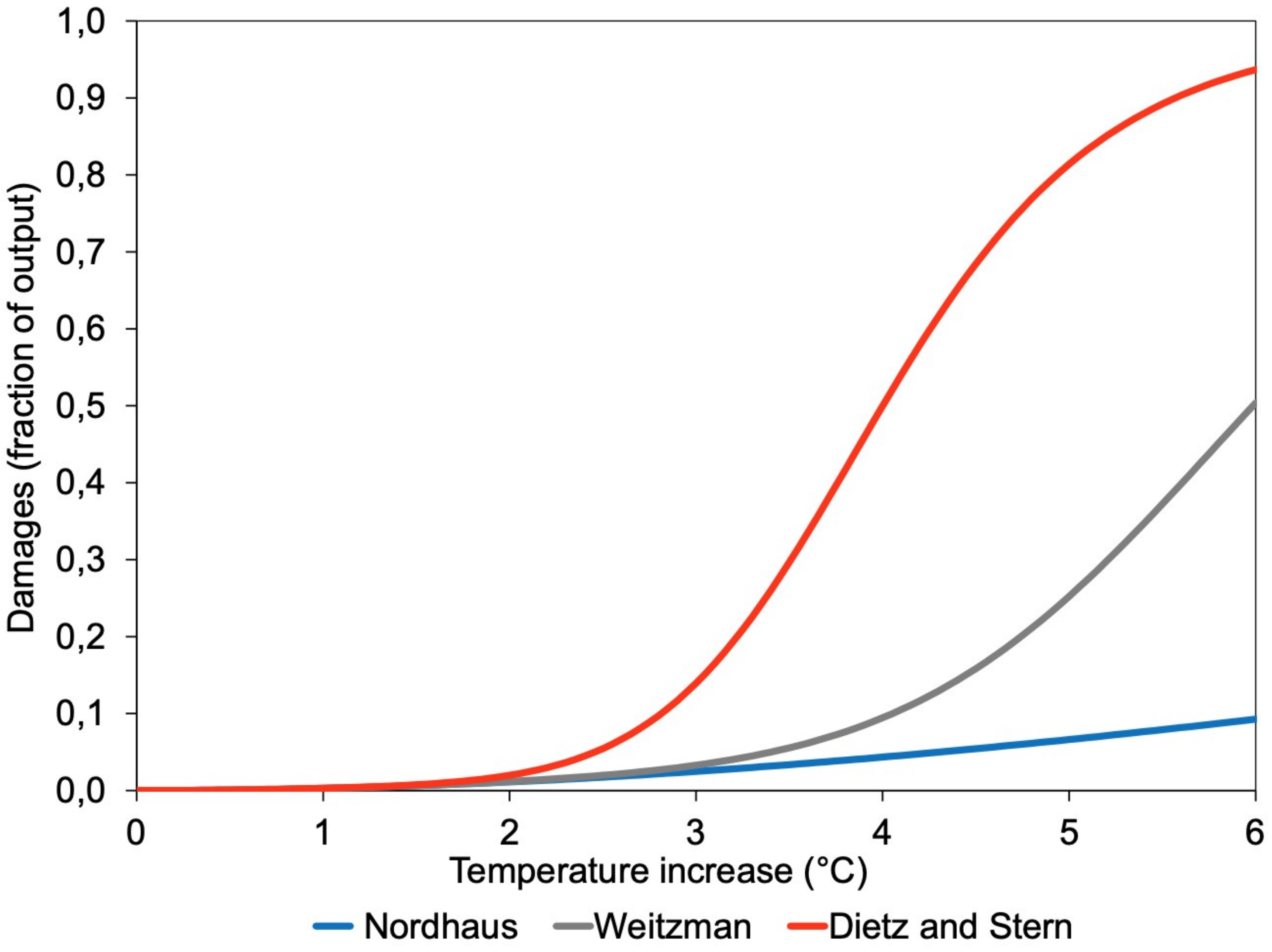
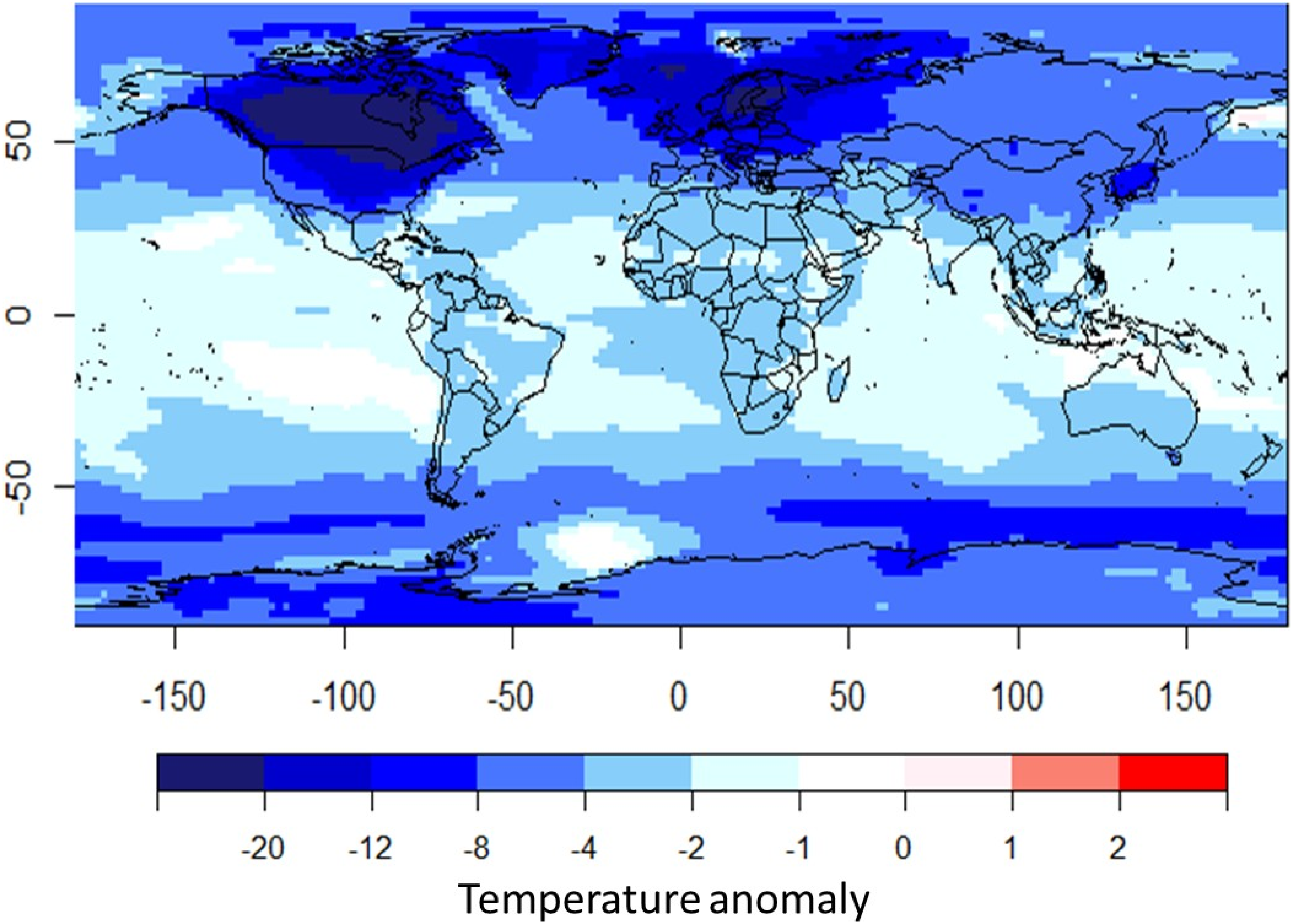


Figure: Shape of various damage functions.

- **Damage functions: are they realistic?**

- Woillez, Giraud & Godin (2020):

- A thought experiment:
- -4°C !



Burke et al. (2015)
and
Newel et al. (2018)

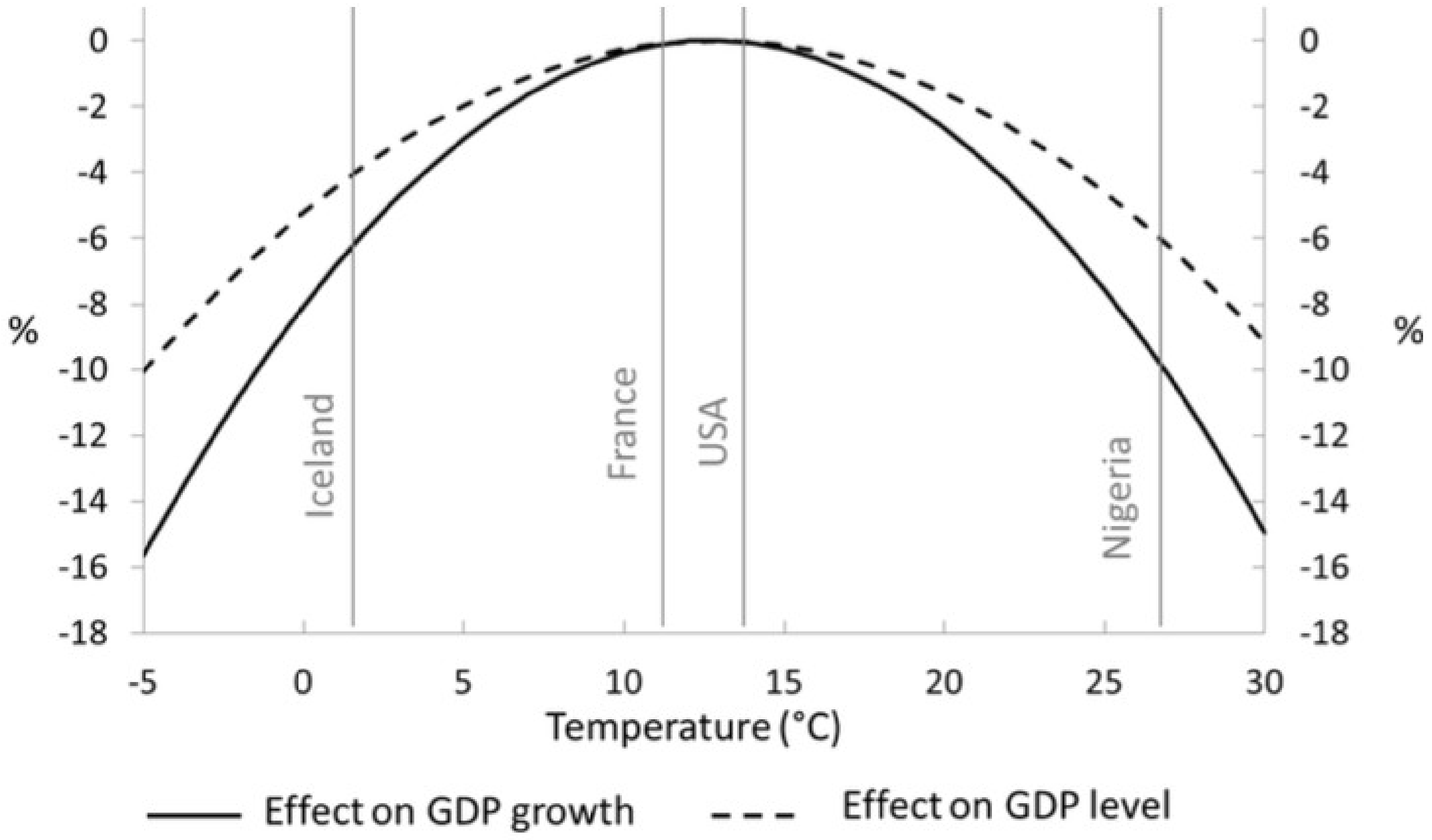


Figure 1. GDP per capita–temperature relationships, growth (BHM), and level (NPS) effects (percentage points). The curves are shown on the same plot but are not directly comparable, since their respective impact on GDP is fundamentally different. Vertical lines indicate average temperature for four selected countries. Each curve has been normalized relative to its own peak.

+300% GDP in Sahelian countries?

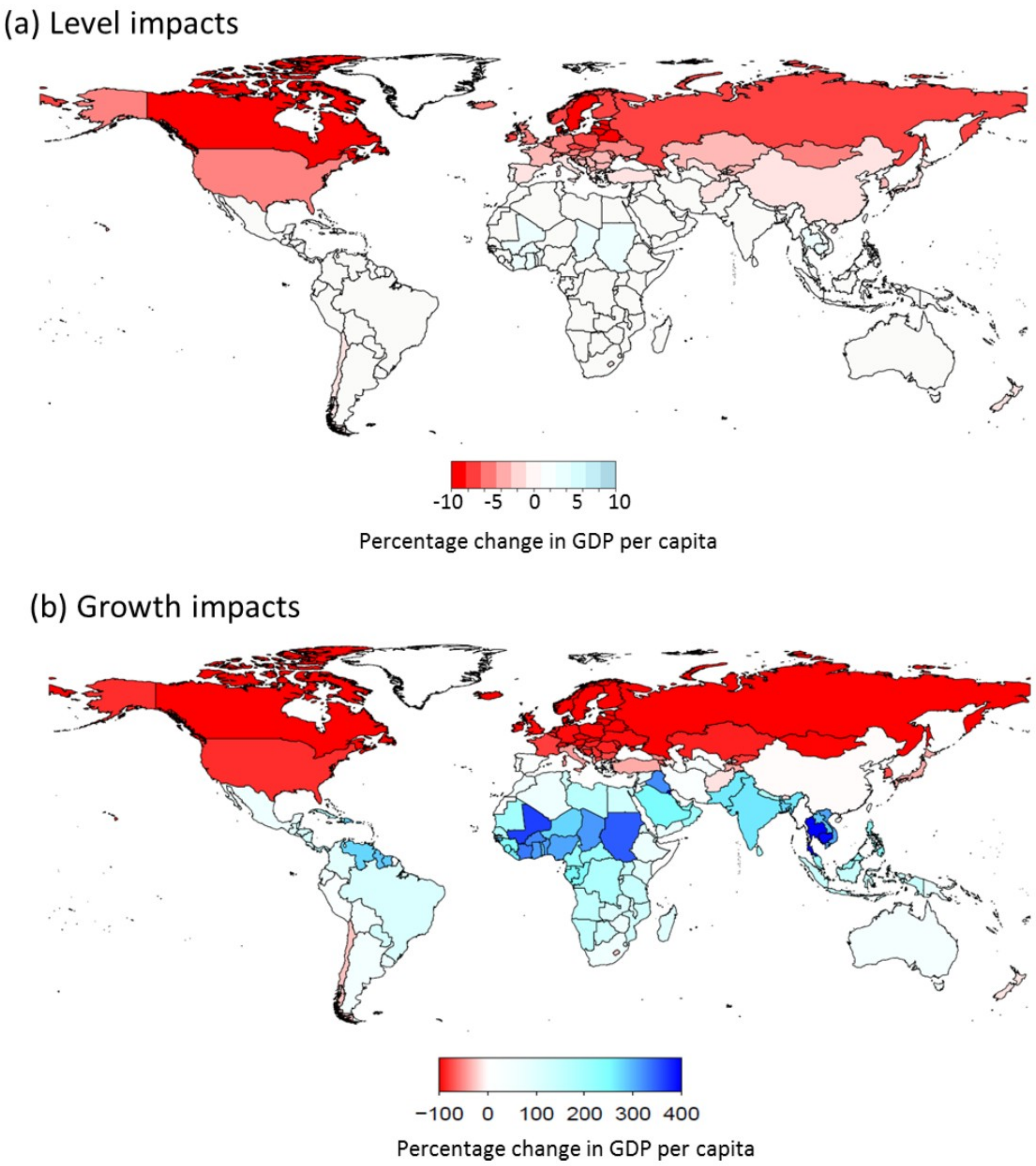
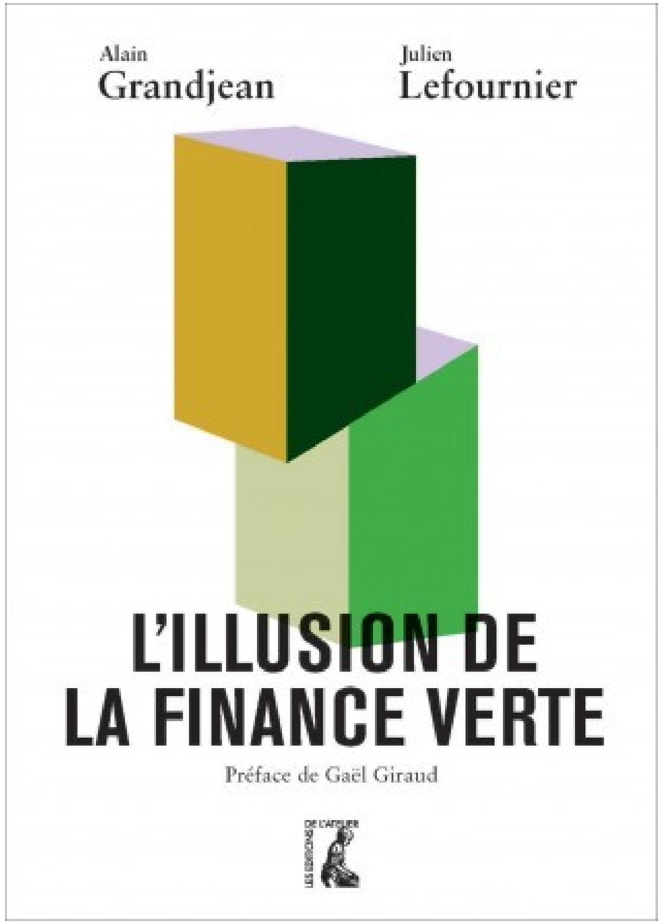


Figure 4. Projected impacts of a 4 °C global cooling on country GDP per capita in 2100. Changes are relative to projections without climate change according to SSP5. **(a)** Changes according to NPS specification (GDP level effects); **(b)** changes according to BHM specification (GDP growth effects). NB: color scales have different maximum and minimum values for easier visualization.

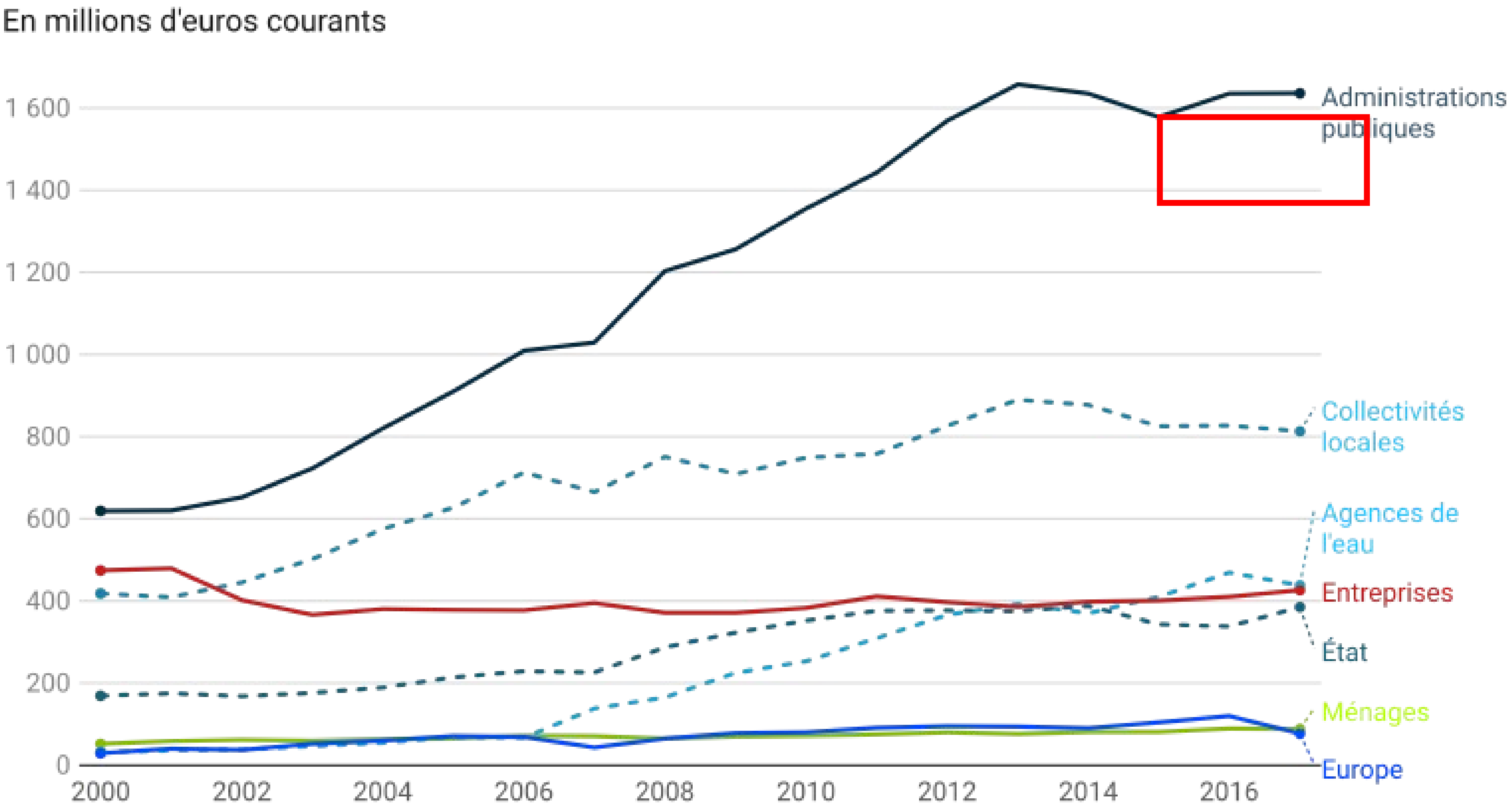


La finance verte

- Additionalité ?
- Sanction prix ?

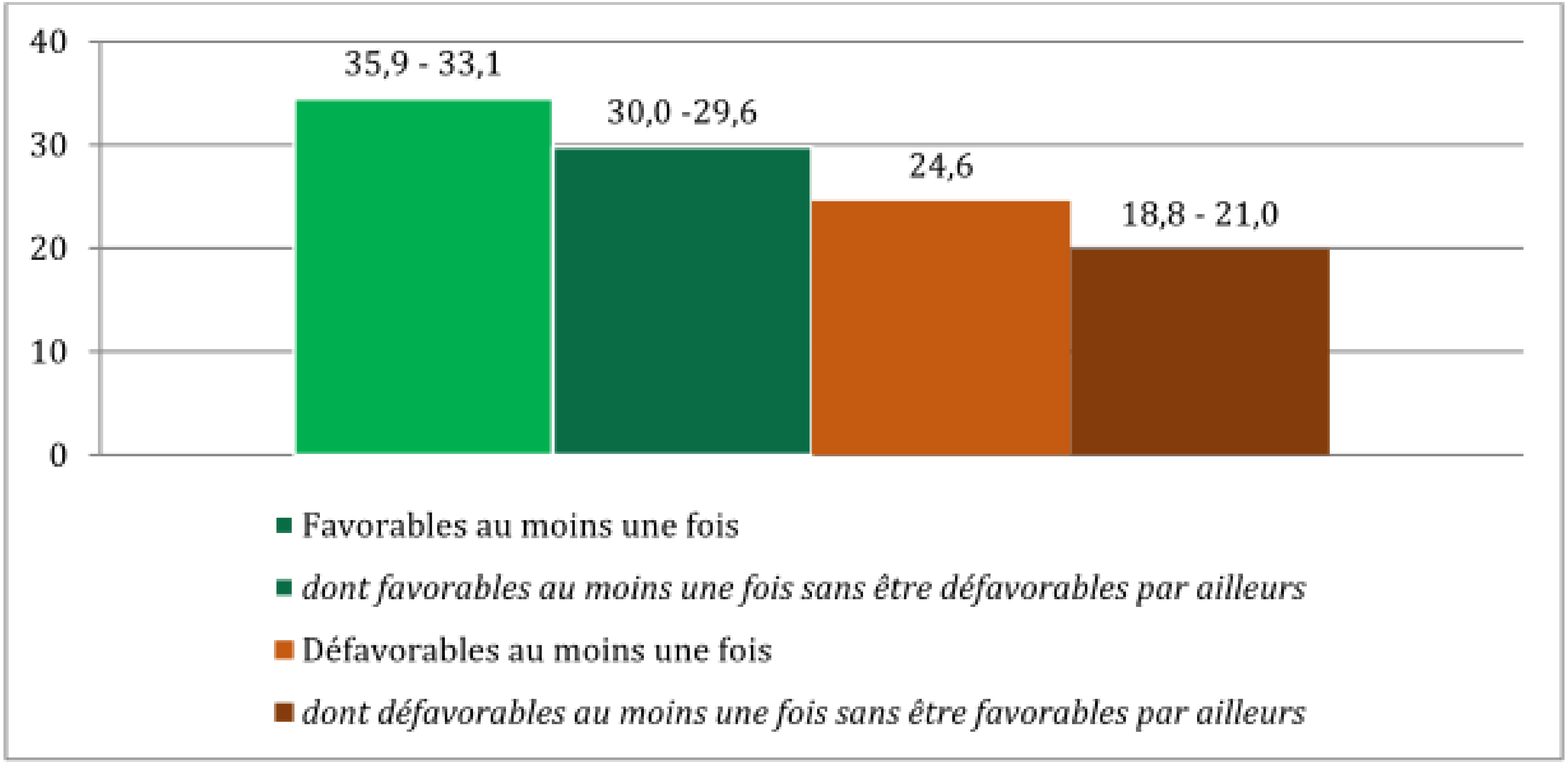
- Bâle IV vert ?
- IFRS/IAS

Evolution of funding for biodiversity protection in France

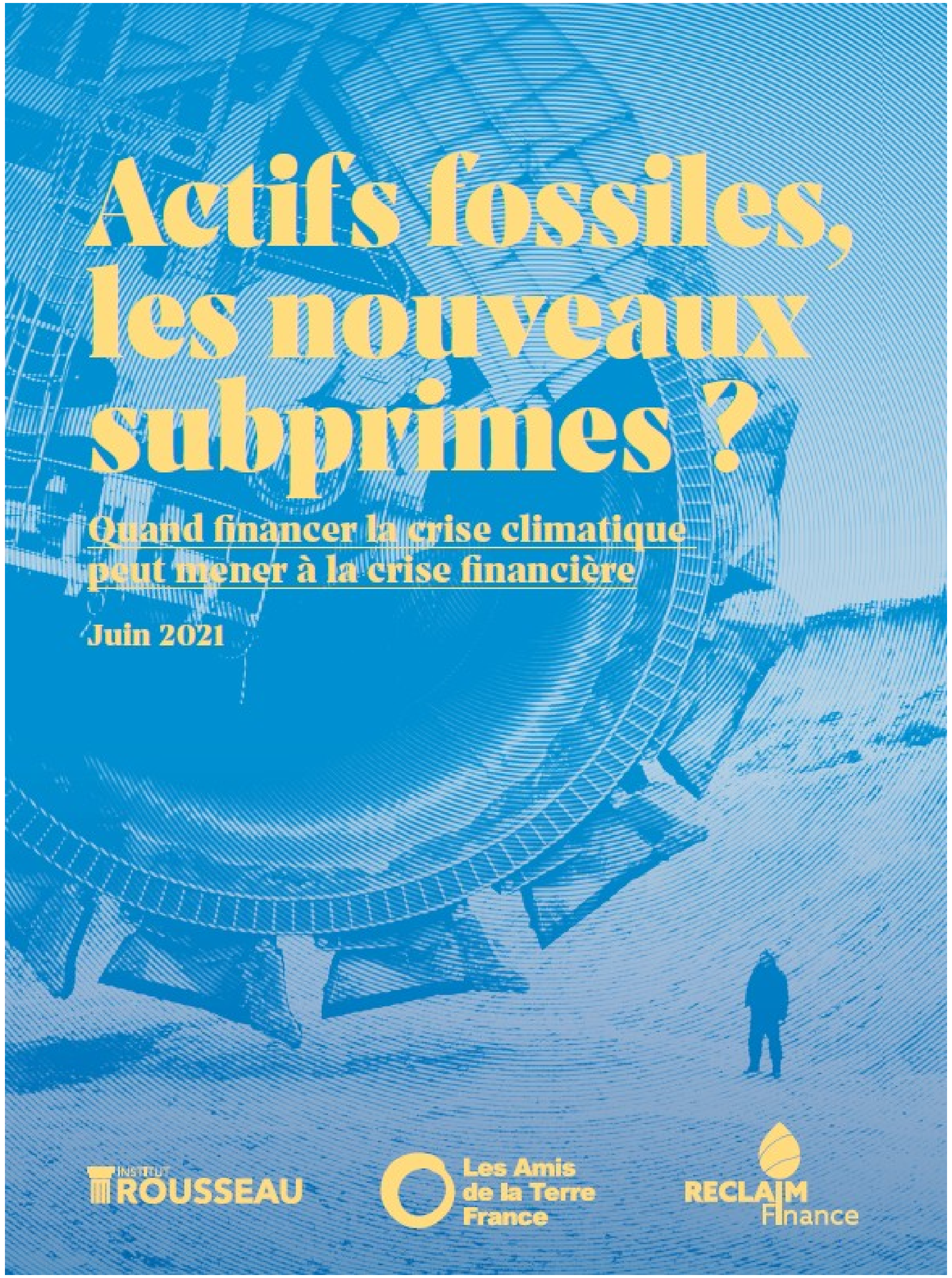


Source: SDES, 2019

Green Public budgeting in France, 2018



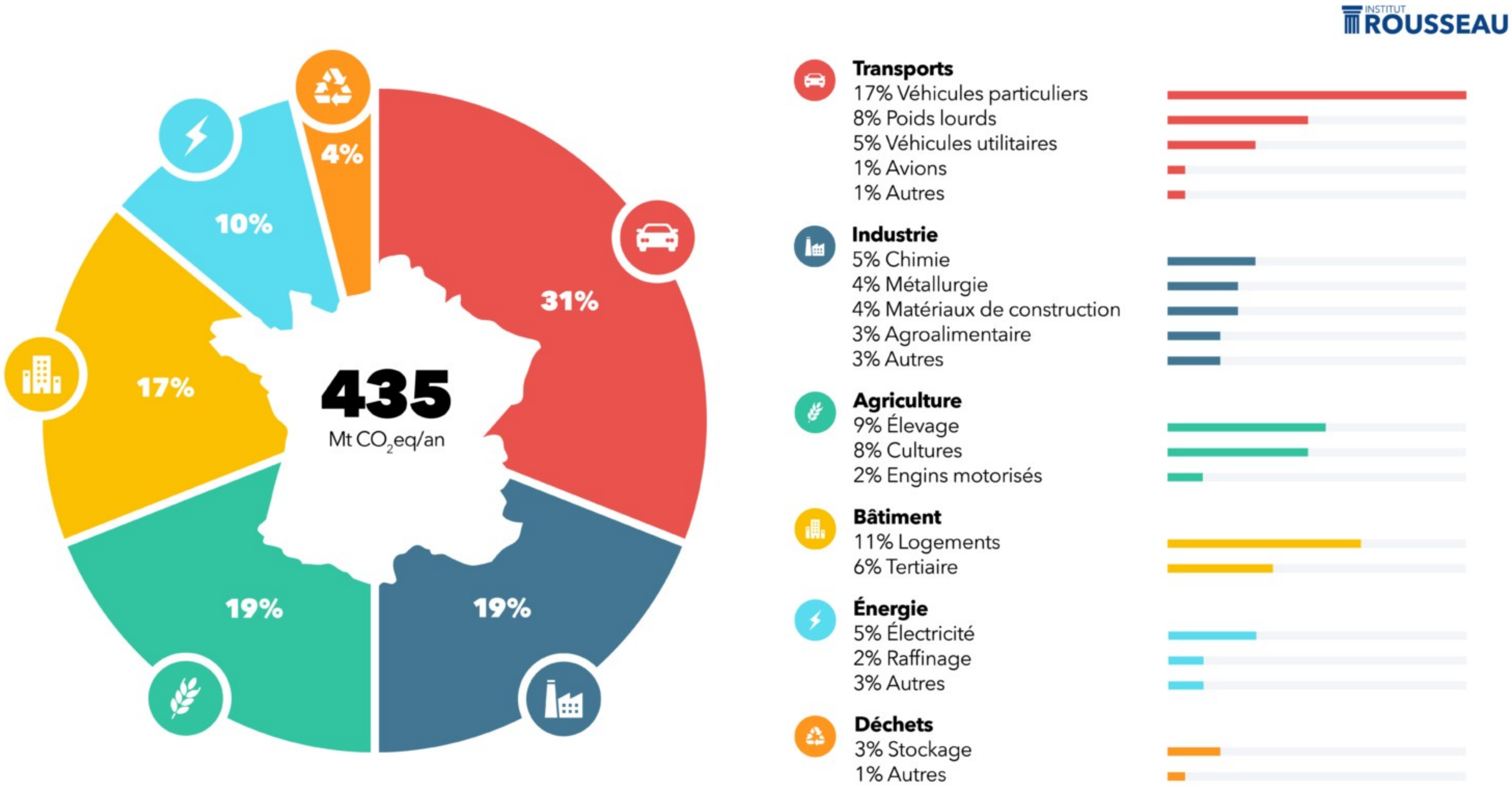
IGF, 2019



INSTITUT ROUSSEAU

1. ECOLOGICAL POLYCRISIS
2. COSTS are HARD to MEASURE
3. 2% for 2°C

INSTITUT
ROUSSEAU



INSTITUT ROUSSEAU
435
Mt CO_2eq/an
31%
19%
19%
17%
10%
4%
Transports
17% Véhicules particuliers
8% Poids lourds
5% Véhicules utilitaires
1% Avions
1% Autres
Industrie
5% Chimie
4% Métallurgie
4% Matériaux de construction
3% Agroalimentaire
3% Autres
Agriculture
9% Élevage
8% Cultures
2% Engins motorisés
Bâtiment
11% Logements
6% Tertiaire
Énergie
5% Électricité
2% Raffinage
3% Autres
Déchets
3% Stockage
1% Autres

Nos 33 leviers pour décarboner la France d'ici 2050

TRANSPORT

1. Réduire le nombre de véhicules et les convertir aux technologies bas-carbone
2. Redévelopper le train
3. Développer les transports en commun et la mobilité douce
4. Réduire l'usage de l'avion et le décarboner
5. Décarboner le transport maritime et fluvial

INDUSTRIE

1. Réduire certaines productions grâce à une sobriété de consommation
2. Augmenter le recyclage des matériaux
3. Développer des procédés de production bas-carbone
4. Relocaliser et développer des filières nationales sur certains secteurs stratégiques pour la transition*

AGRICULTURE

1. Convertir l'ensemble du secteur à l'agro-écologie
2. Réduire la taille du cheptel bovin et la consommation de viande
3. Réduire la production de méthane des ruminants
4. Augmenter la part de déjections animales valorisées en méthanisation
5. Convertir les tracteurs aux technologies bas-carbone

BATIMENT

1. Rénover massivement et globalement les logements
2. Rénover massivement et globalement le parc tertiaire public et privé
3. Réduire le rythme de construction neuve

PRODUCTION D'ENERGIE

1. Décarboner et adapter le système de production d'électricité
2. Remplacer le gaz naturel par du biogaz et autres gaz « verts »
3. Sortir du pétrole et cesser son raffinage
4. Décarboner la production de chaleur pour le chauffage urbain et autres émissions résiduelles (incinération, etc.)

DECHETS

1. Collecter séparément et méthaniser les déchets organiques fermentescibles
2. Développer l'économie circulaire et l'économie de la fonctionnalité

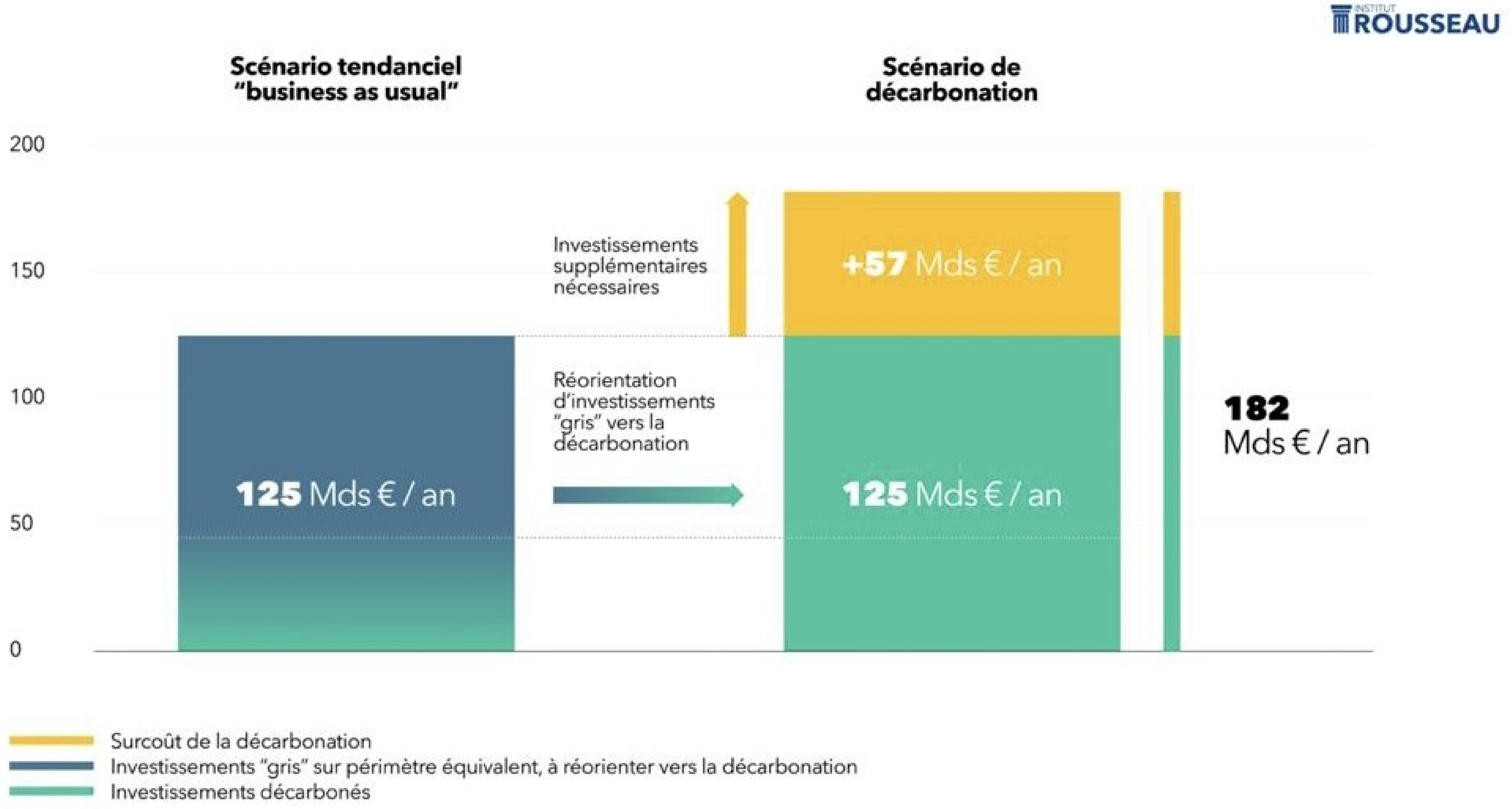
PUITS DE CARBONE

1. Augmenter la superficie forestière et les moyens affectés à sa bonne gestion
2. Planter des lignes de haies et des arbres en plein champs
3. Faire appel, lorsque pertinent, aux technologies de Captage et Stockage du CO_2

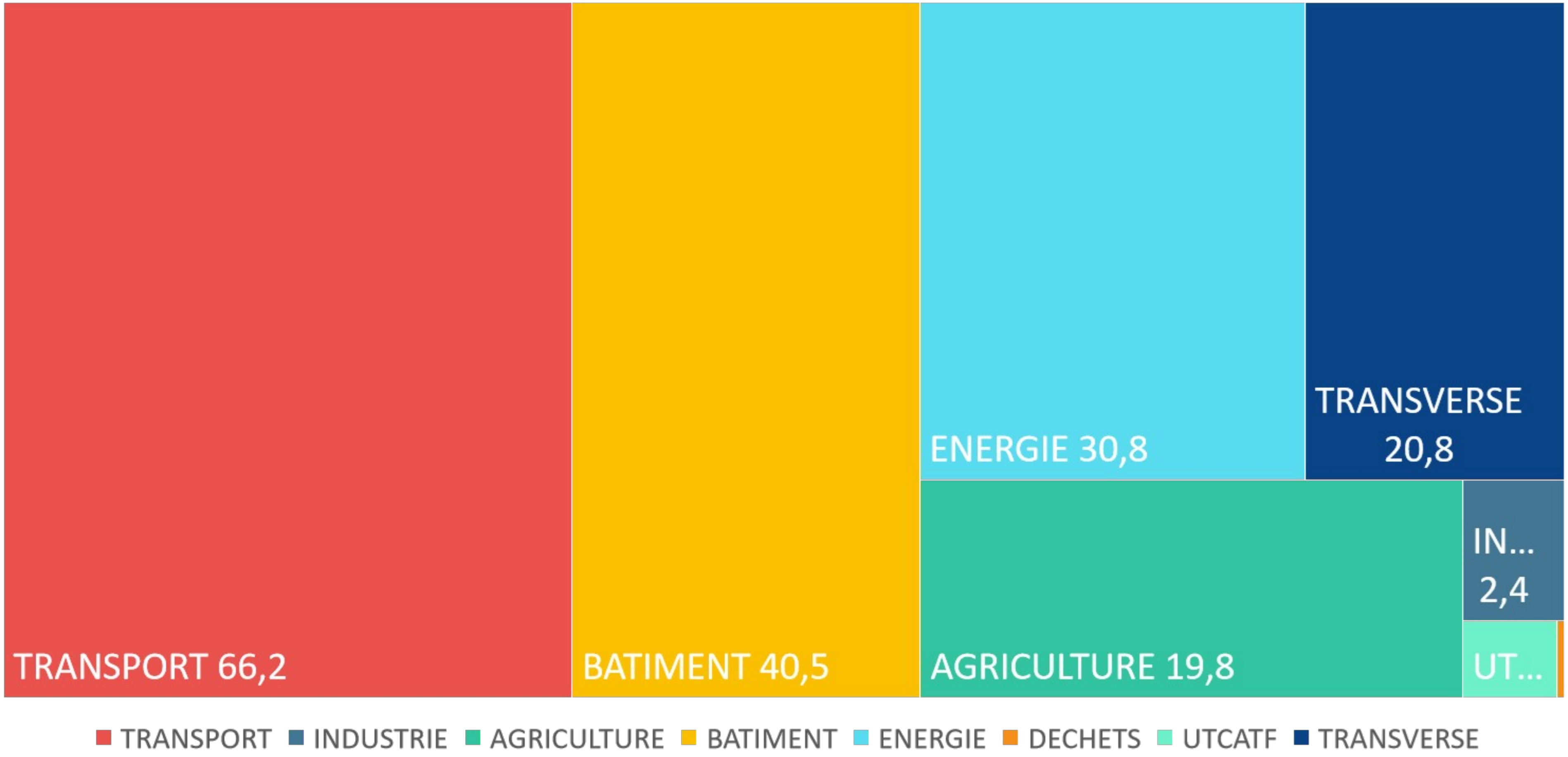
LEVIERS TRANS-SECTORIELS

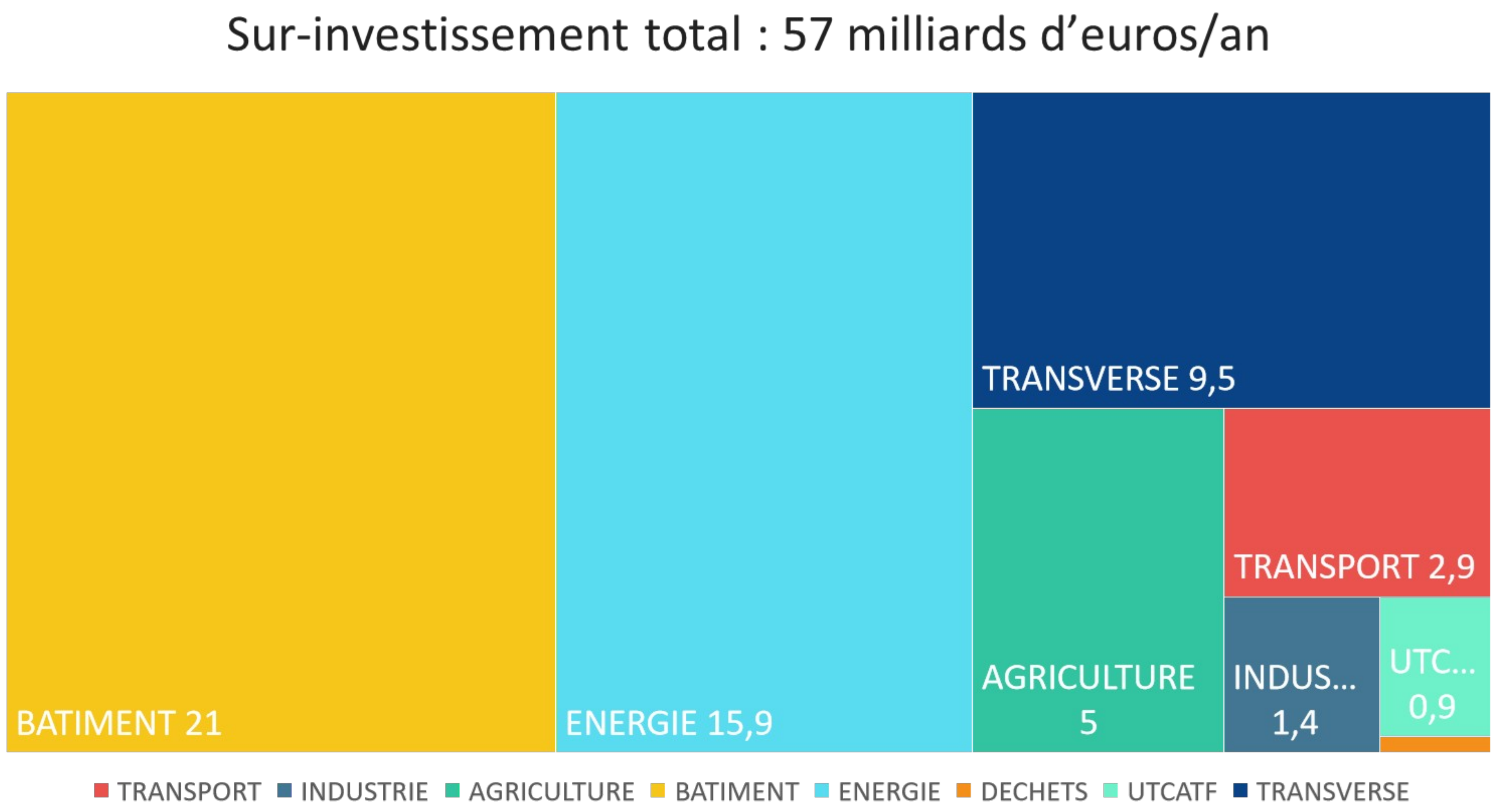
1. Engager les effectifs publics nécessaires pour accompagner la transition écologique
2. Booster la R&D et l'innovation appliquée à la transition écologique
3. Utiliser davantage les possibilités offertes par les banques publiques d'investissement
4. Adapter la formation initiale aux enjeux de la transition écologique
5. Sensibiliser les citoyens aux enjeux de la transition écologique et aux solutions associées
6. Soutenir le développement d'un numérique moins émetteur
7. Accompagner les mutations professionnelles engendrées par la transition

INSTITUT ROUSSEAU

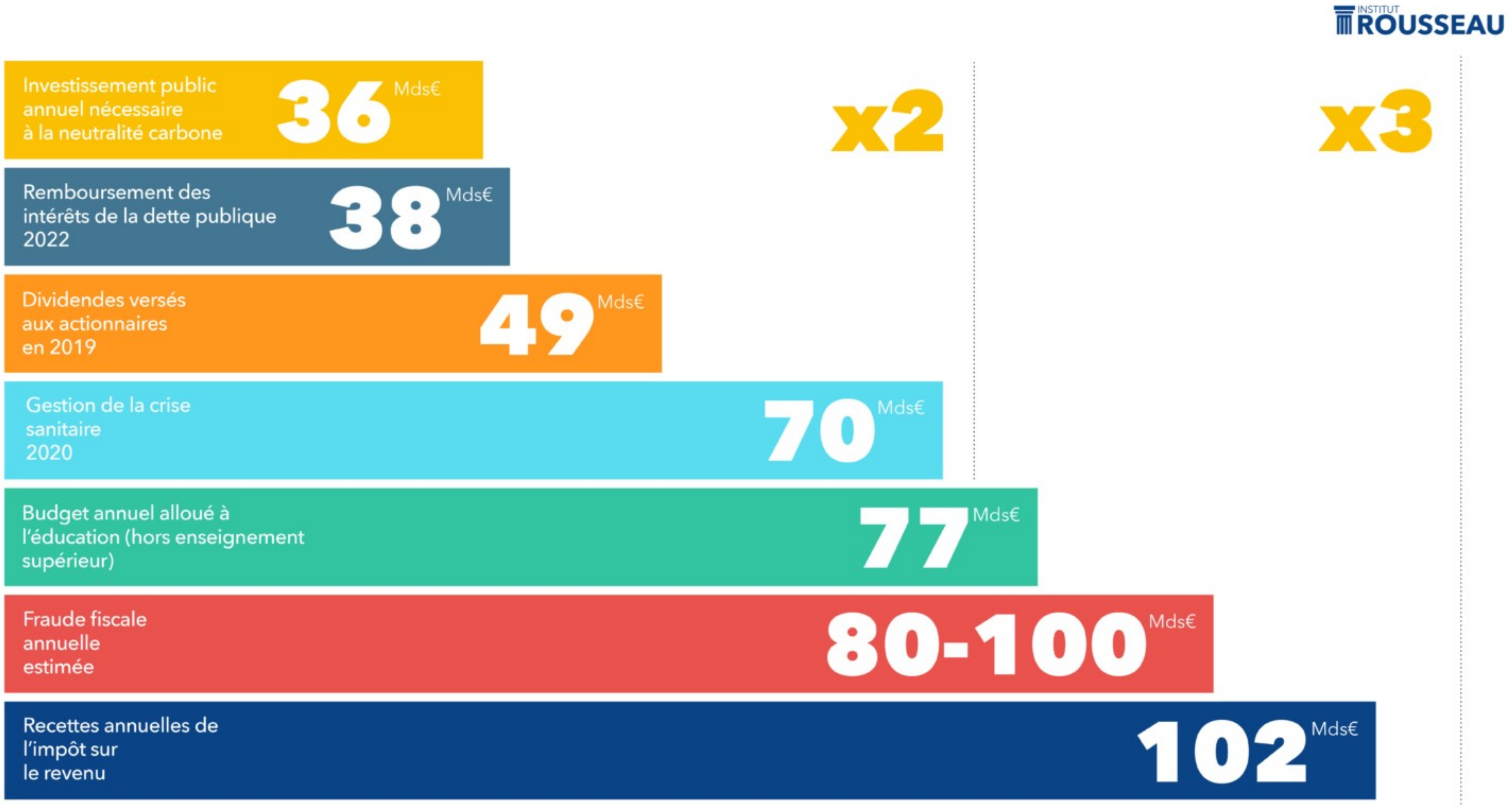

INSTITUT ROUSSEAU
Scénario tendanciel "business as usual"
Scénario de décarbonation
200
150
100
50
0
Investissements supplémentaires nécessaires
+57 Mds € / an
Réorientation d'investissements "gris" vers la décarbonation
125 Mds € / an
125 Mds € / an
182 Mds € / an
Surcoût de la décarbonation
Investissements "gris" sur périmètre équivalent, à réorienter vers la décarbonation
Investissements décarbonés

Investissement total : 182 milliards d'euros/an

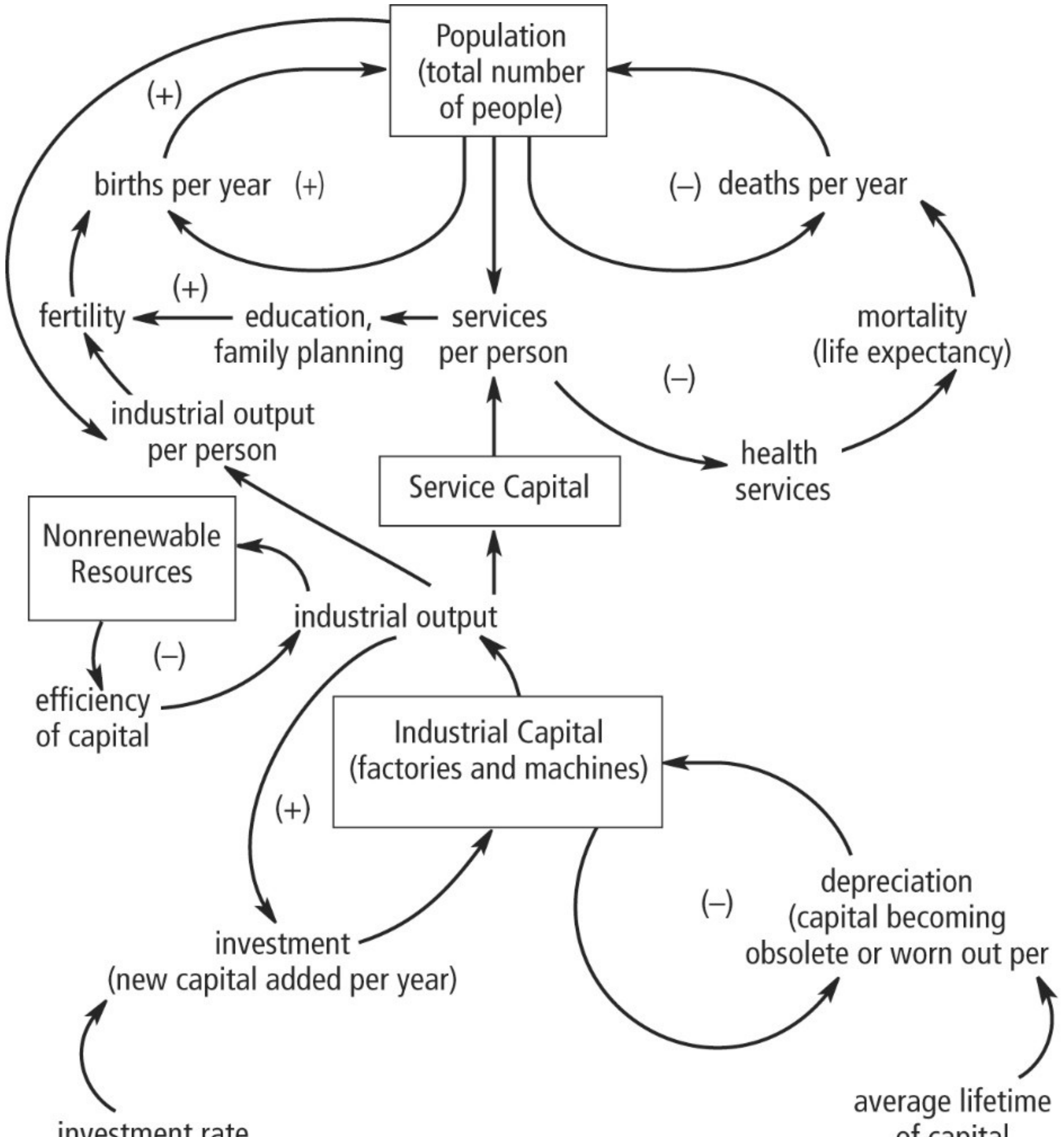



Sur-investissement total : 57 milliards d'euros/an
BATIMENT 21
ENERGIE 15,9
TRANSVERSE 9,5
AGRICULTURE 5
TRANSPORT 2,9
INDUS... 1,4
UTC... 0,9
TRANSPORT
INDUSTRIE
AGRICULTURE
BATIMENT
ENERGIE
DECHETS
UTCATF
TRANSVERSE

Quelques comparaisons du surcoût public



Non-linear Dynamics induced by multiple back-loops



1. ECOLOGICAL POLYCRISIS
2. COSTS are HARD to MEASURE
3. 2% for 2°C
4. COPPING with COLLAPSE