The impact of climate transition risks on financial stability. A systemic risk approach.

Javier Ojea-Ferreiro*[2] Juan Carlos Reboredo† Andrea Ugolini°

*Joint Research Centre of the European Commission (JRC) *javier.ojea-ferreiro@ec.europa.eu*

†Universidade de Santiago de Compostela (USC) *juancarlos.reboredo@usc.es*

°University of Milan-Bicocca *andrea.ugolini@unimib.it*

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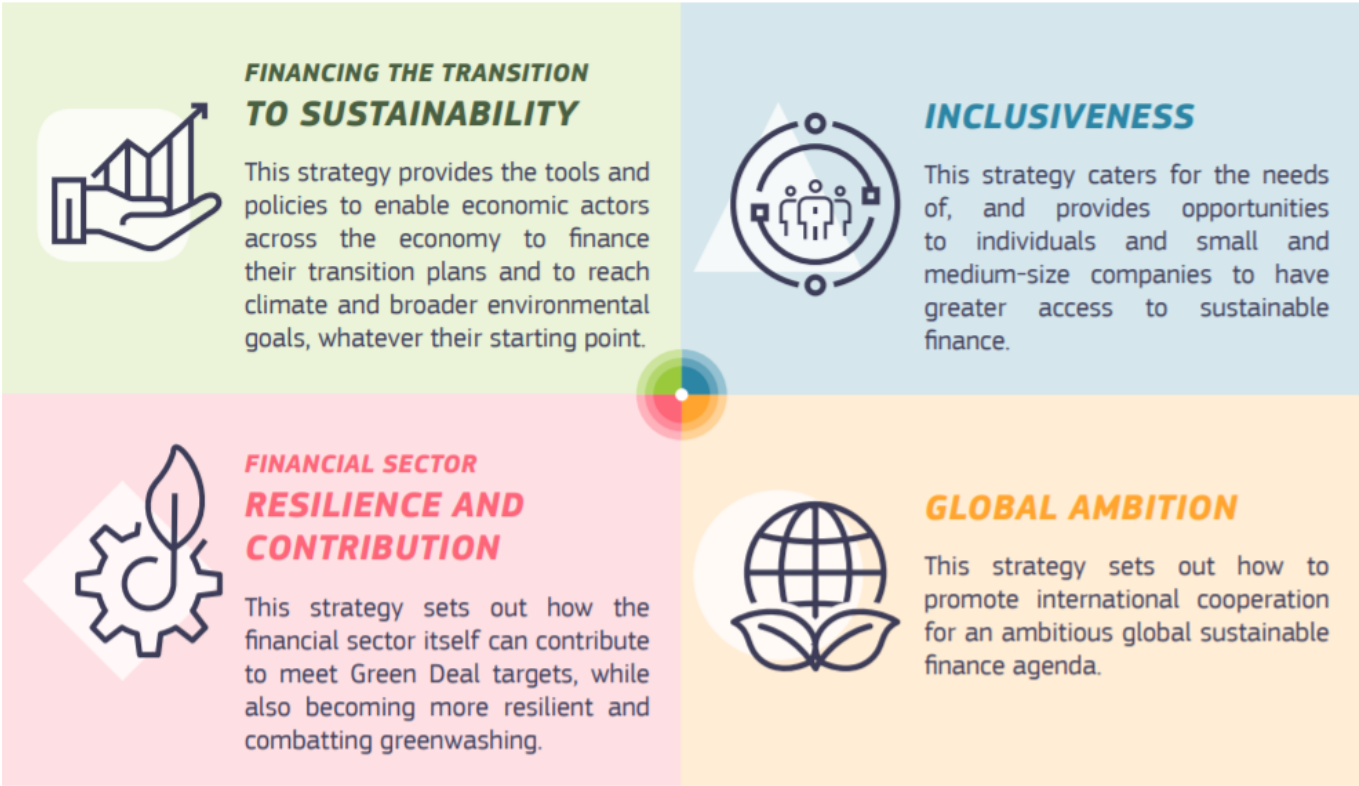
[2] **Disclaimer:** The views expressed are those of the author and do not necessarily reflect those of the JRC.

Overview

Overview

EU Sustainable Finance Strategy

- Complete the work started under the 2018 Action Plan on Financing Sustainable Growth
- An evolved context provides need for additional measures in four key areas



EU Sustainable Finance Strategy

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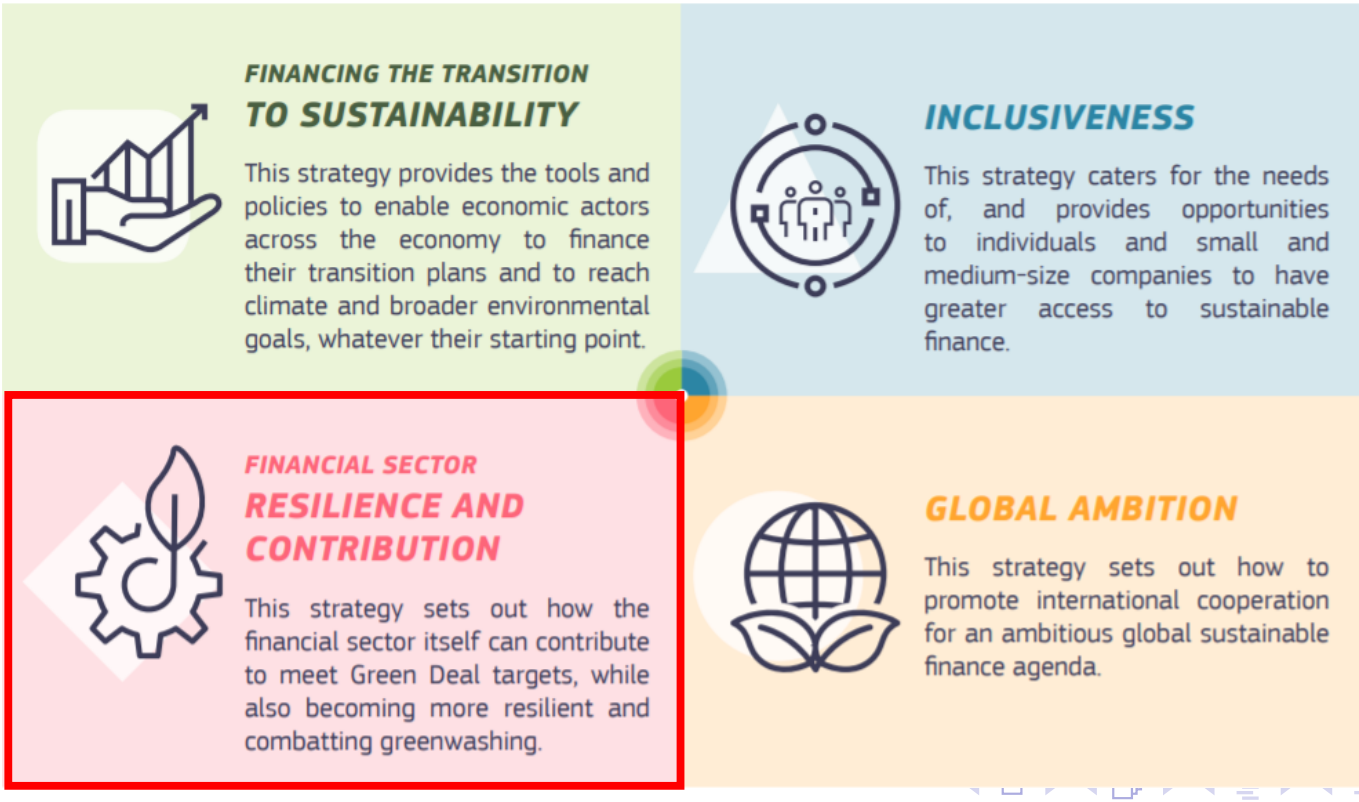


Strategy for financing the transition to a sustainable economy

Improving the financial sector's resilience and contribution to sustainability

Integrate sustainability risks in the risk management systems of banks and in the prudential framework for insurers.

Monitor and address potential systemic risks stemming from sustainability challenges, with the aim of maintaining long-term financial stability and limiting systemic risk.

Develop a robust monitoring framework to measure progress made by the EU financial system.

Improve the cooperation between authorities to monitor the alignment of the EU financial system with Green Deal targets.

The financial sector will play a critical role in our transition to sustainability

> Monitor and address potential systemic risks stemming from sustainability challenges, with the aim of maintaining long-term financial stability and limiting systemic risk.

Climate risk to systemic risk

- Monitor and address systemic risks stemming from climate challenges
  - How do financial firms behave in a coherent narrative with the NGFS scenario?
  - How would financial institutions be affected by their exposure to carbon-intensive assets and sectors?

The financial sector will play a critical role in our transition to sustainability

> Integrate sustainability risks in the risk management systems of banks and in the prudential framework for insurers.

Climate risk to systemic risk

- Integrate climate transition risk in the risk management of financial institutions
  - How much capital would financial firms need in case of a climate transition scenarios?
  - How do different scenarios impact on benchmark risk measures of financial firms?
  - Do answers to previous questions depend on the business model of financial institutions?

The financial sector will play a critical role in our transition to sustainability

> Develop a robust monitoring framework to measure progress made by the EU financial system.

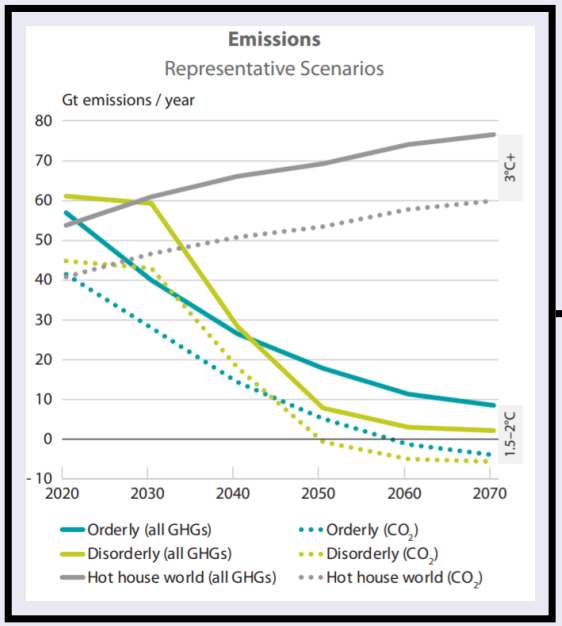
Climate risk to systemic risk

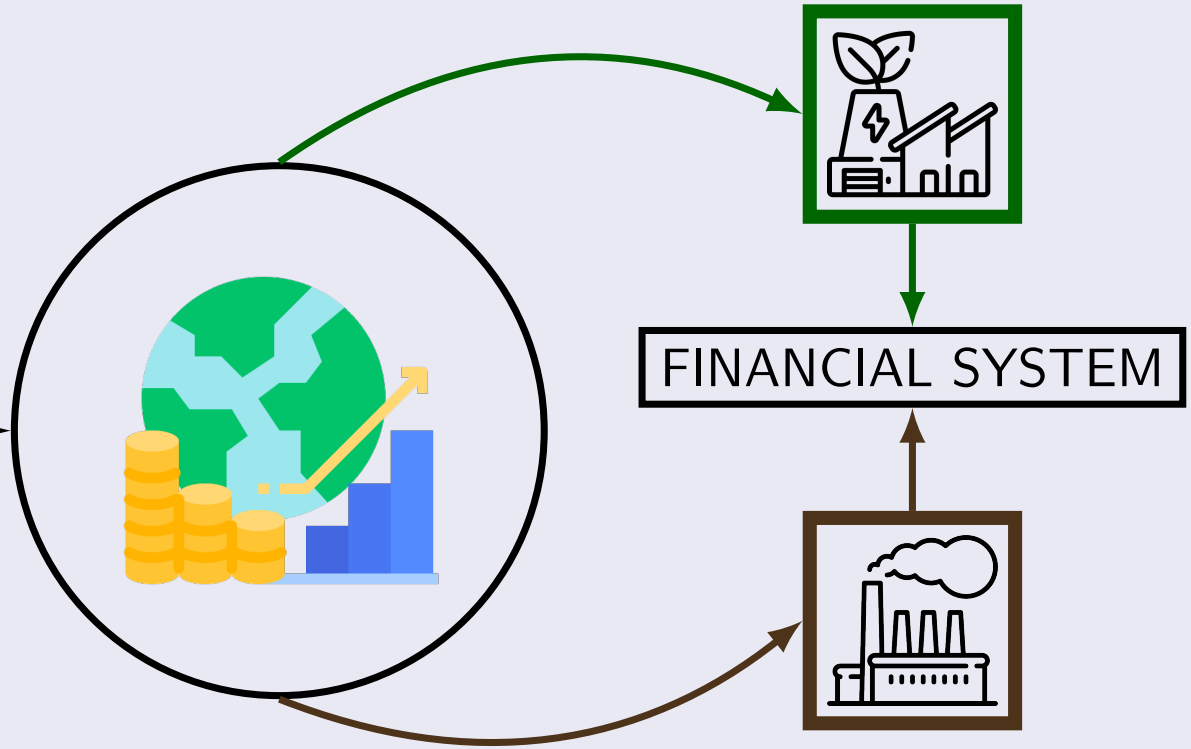
- Develop a robust monitoring framework to measure the systemic risk coming from climate transition risk. Perform scenario analysis to test strategic resilience.
  - Can we assess these questions using public data and a methodology easy to replicate?

The climate transition narrative

From NGFS scenarios to stock price adjustments

- Different **transition scenarios** imply changes in the speed of the process that modify **current expectation** of the economic agents, leading to **asset price adjustments**.





Disorderly transition scenario

- **Green firms**
  - Anticipate opportunities in the transition.
  - Flight-to-green behaviour of investors.
- **Brown firms**
  - Difficulties to absorb stranded asset in the new framework.
  - Stigmatization of sector.
  - Carbon tax burden.

Hot house world scenario

- **Green firms**
  - Competitive disadvantages against carbon-intensive firms.
  - Lack of support for renewable energies.
- **Brown firms**
  - High-carbon assets take longer than expected to become stranded assets. Expected devaluation in products is not materialized.

– Disruption in current business models due to a change in the **timing and speed of the adjustment** towards a low-carbon economy.

Empirical set-up to analyse the financial system performance conditional on different climate transition scenarios

- Climate transition scenarios translated into a coherent combination of green, neutral and brown stock portfolios.
  - **Orderly transition scenario:** green, neutral and brown portfolios are around their median returns.
  - **Disorderly transition scenario:** green portfolio value surges and brown portfolio value plunges.
  - **Hot house world scenario:** green portfolio sharply decreases and brown portfolio experiences an acute increase.
- Systemic risk measures adapted to climate transition (CT) scenarios ([Adrian and Brunnermeier, 2016], [Girardi and Ergün, 2013]).

Overview

Capturing the joint distribution

Copula approach here

- Straightforward decomposition of the joint distribution function

$$F(r_g, r_n, r_b, r_i) = C_{g,n,b,i}(F_g(r_g), F_n(r_n), F_b(r_b), F_i(r_i))$$

- Dynamics following [Patton, 2006]'s specification.
- Asymmetry behaviour and tail dependence.

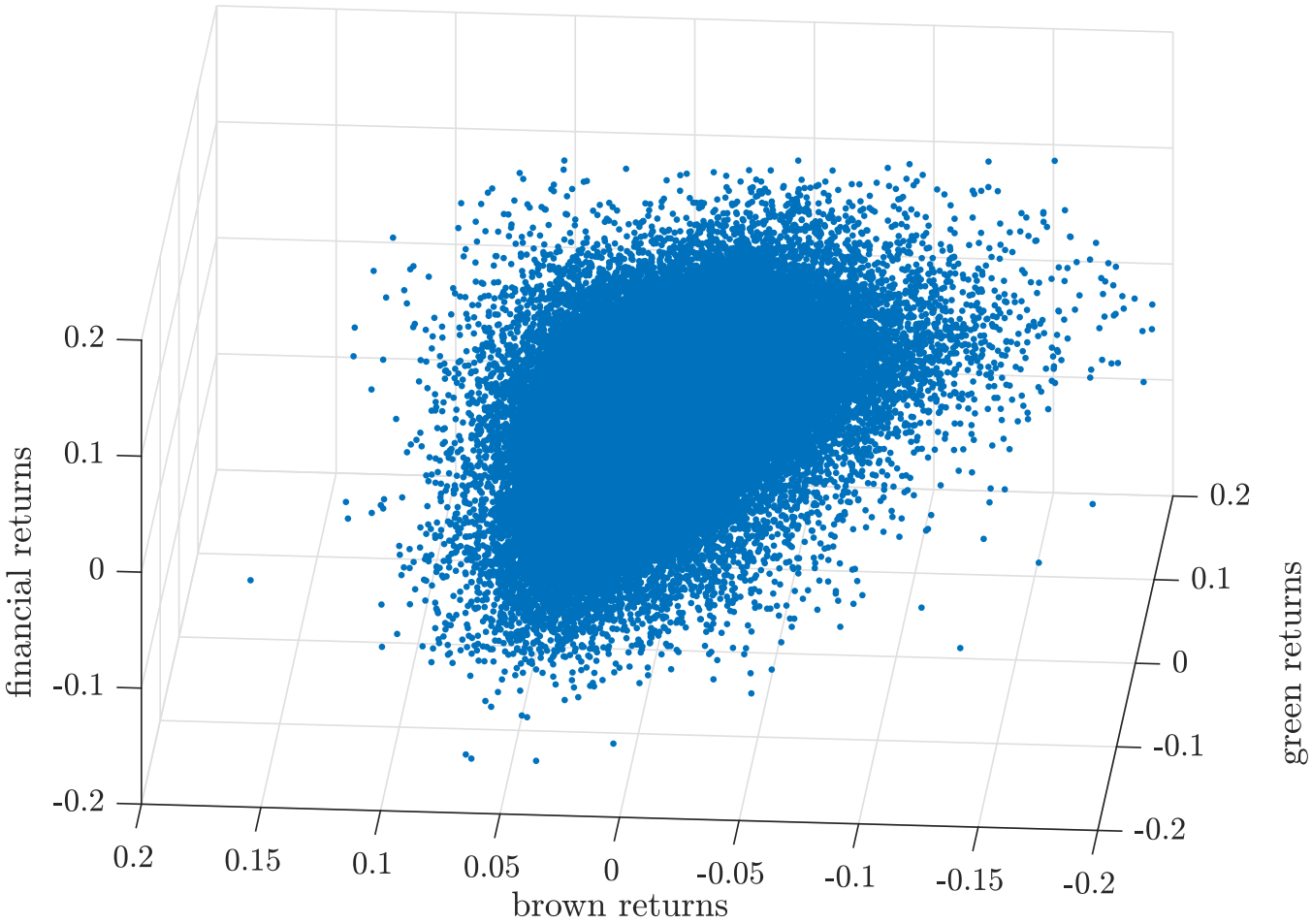
Vine copula extension here

- Hierarchical bivariate copulas to generate complex multivariate dependence

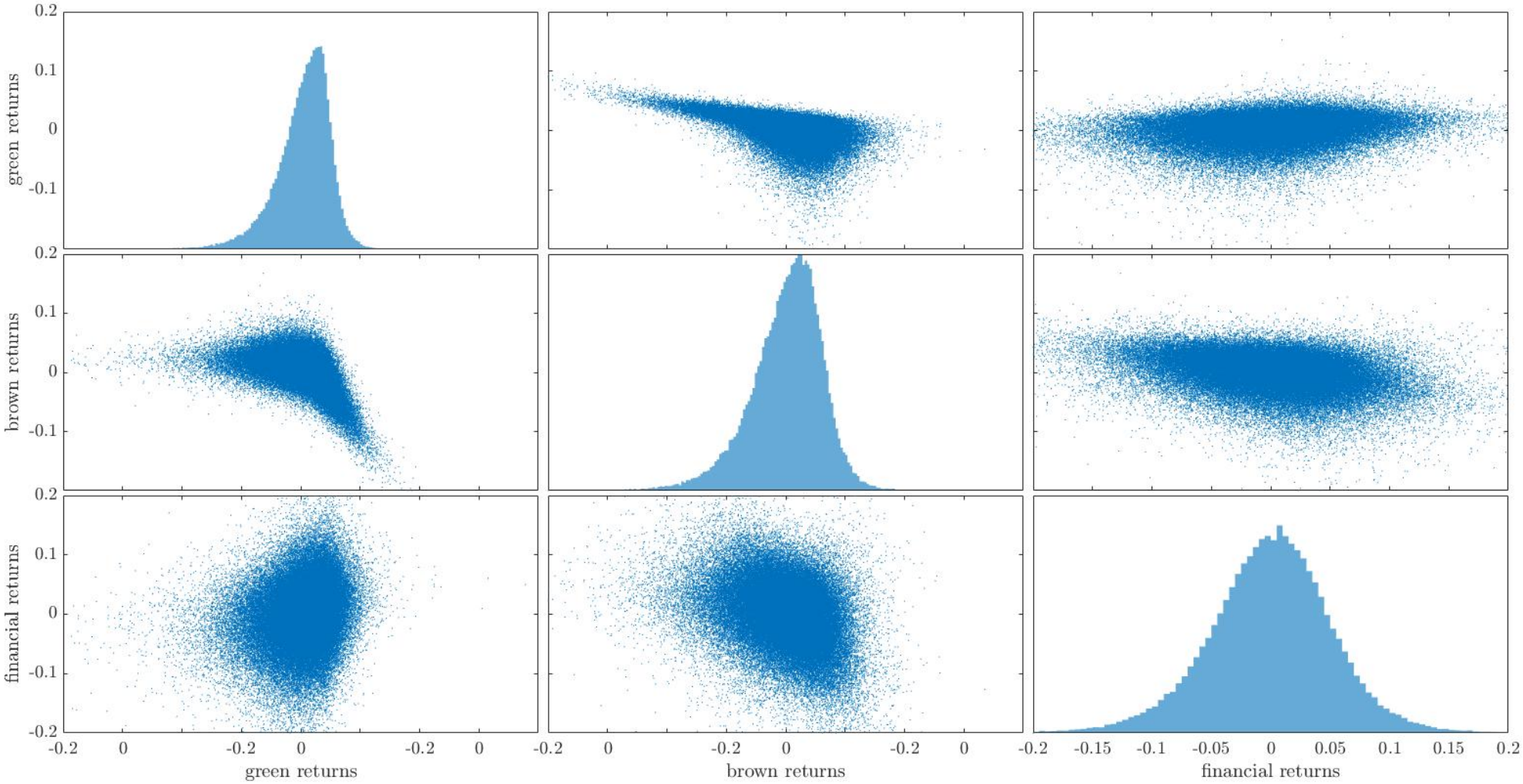
Marginal model

$ARMA(p, q)$ $GJR - GARCH(h, k)$ & skewed-t Student distribution.

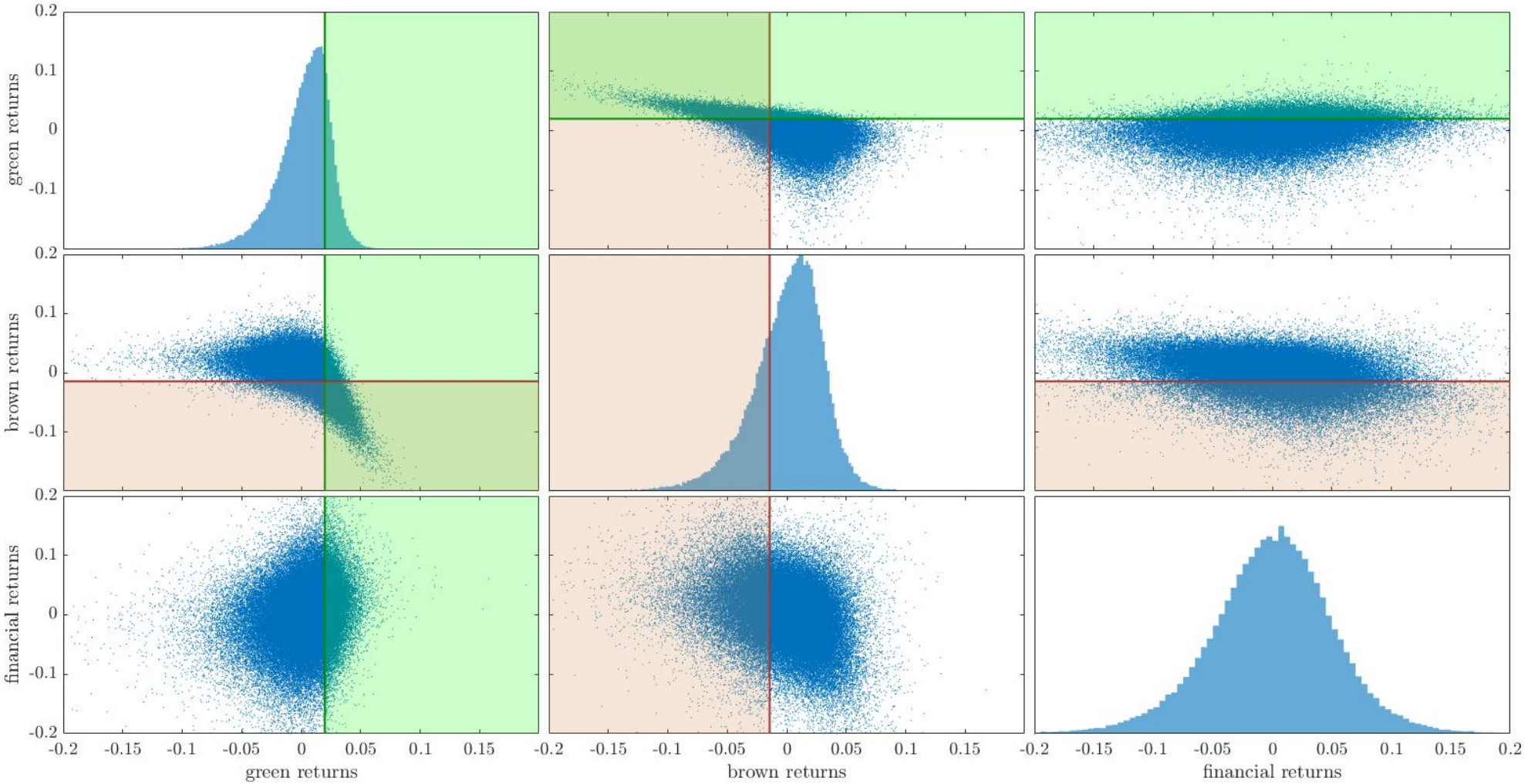
Building risk measures in climate scenarios



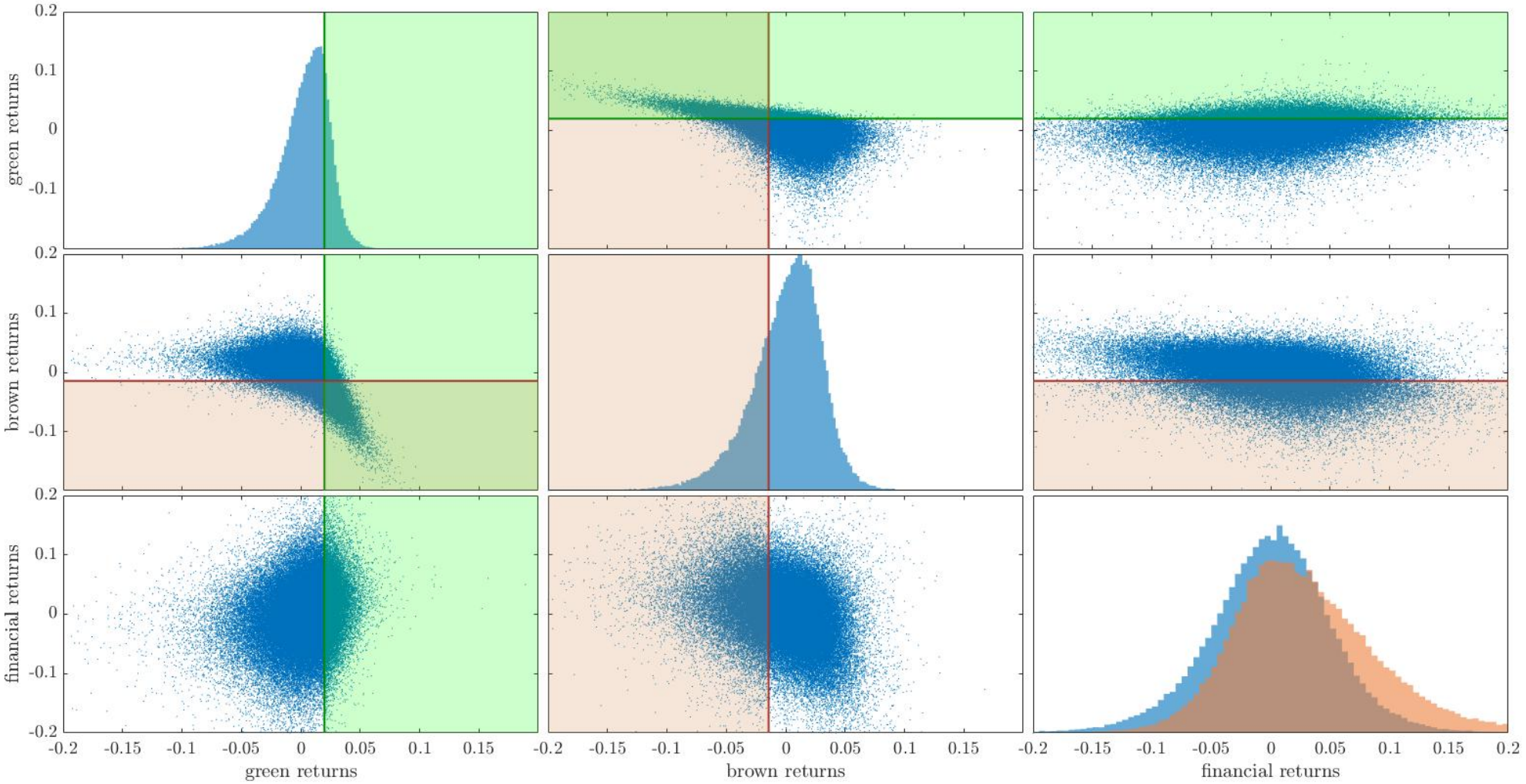
Building risk measures in climate scenarios



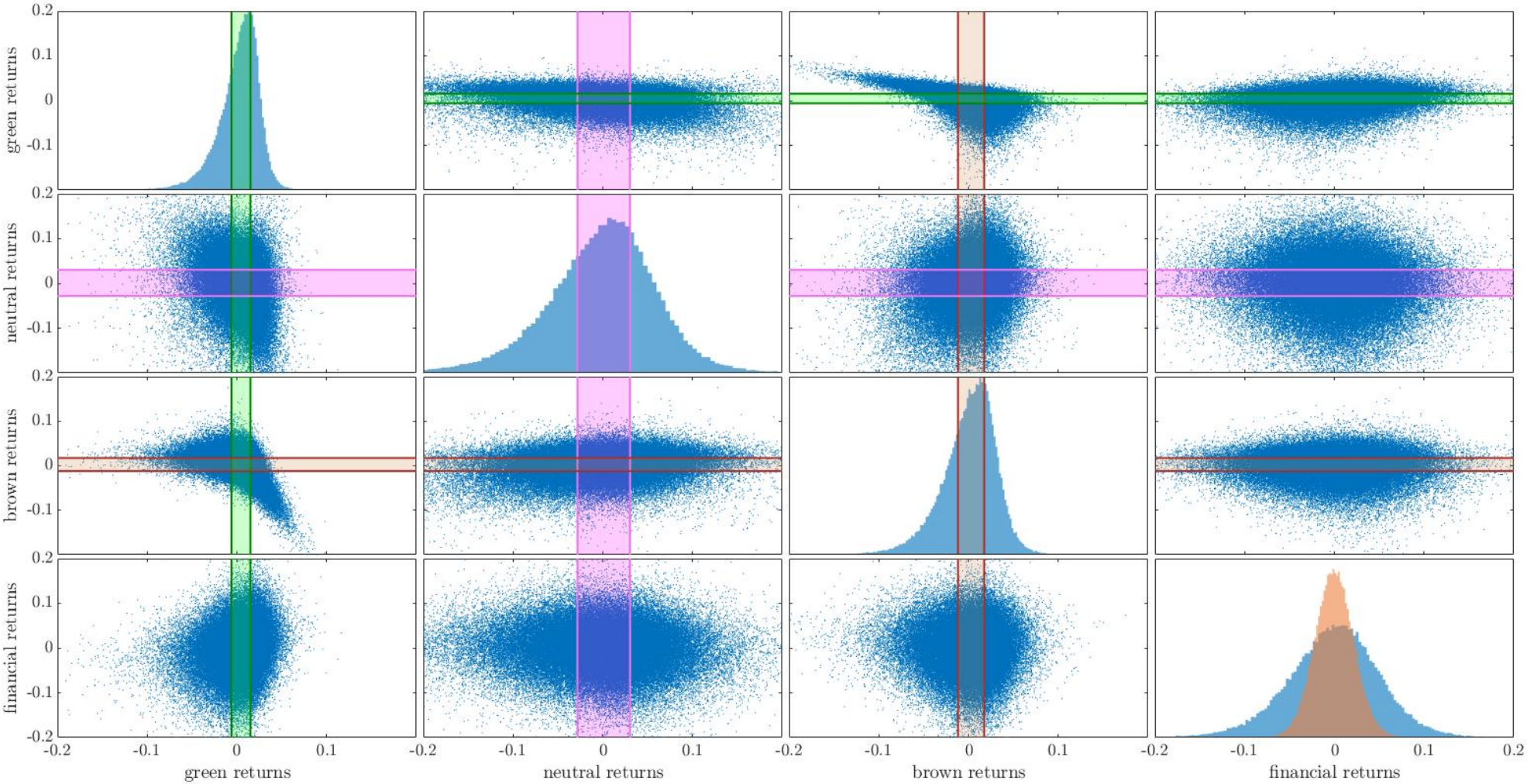
Disorderly transition climate scenario



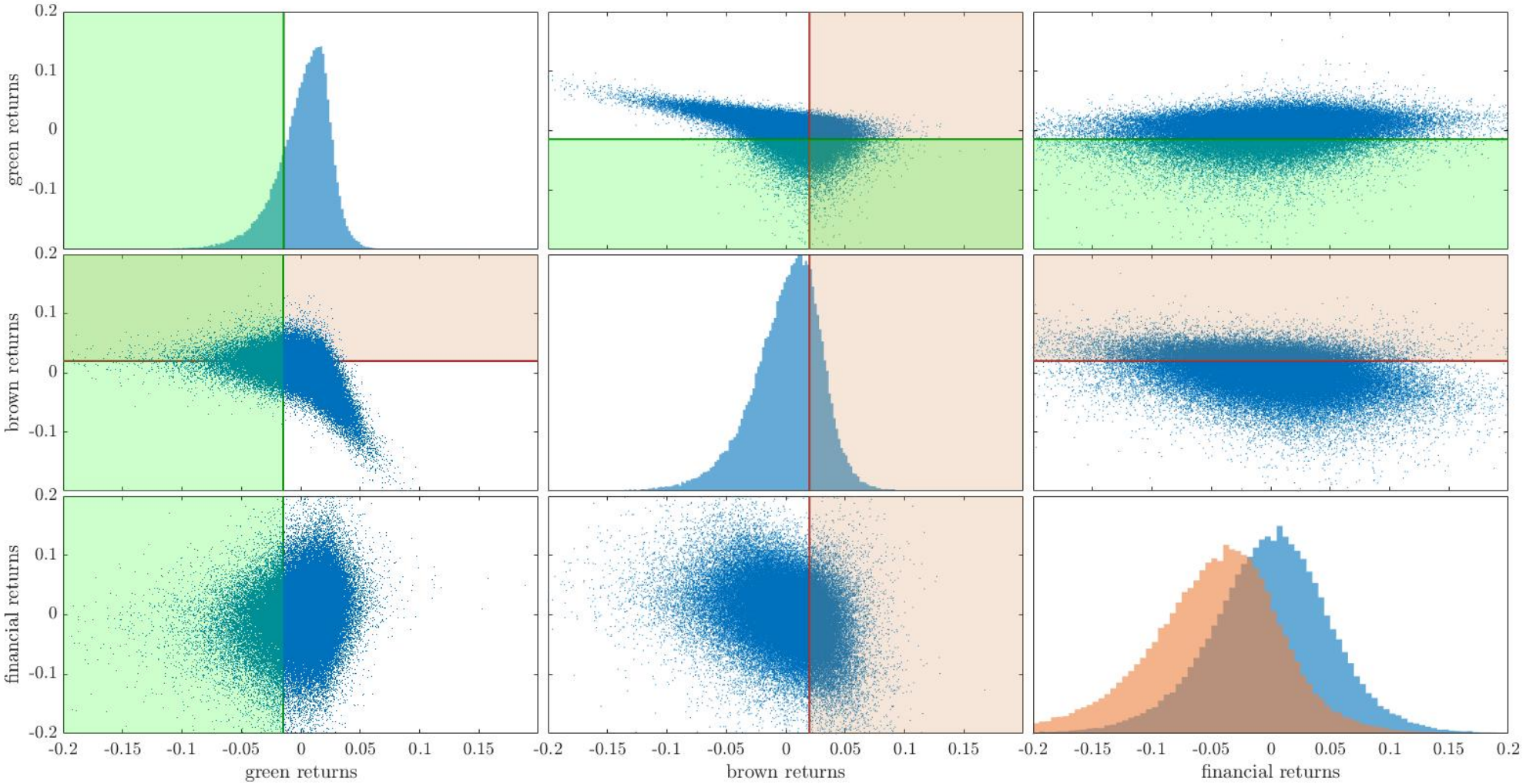
Disorderly transition climate scenario



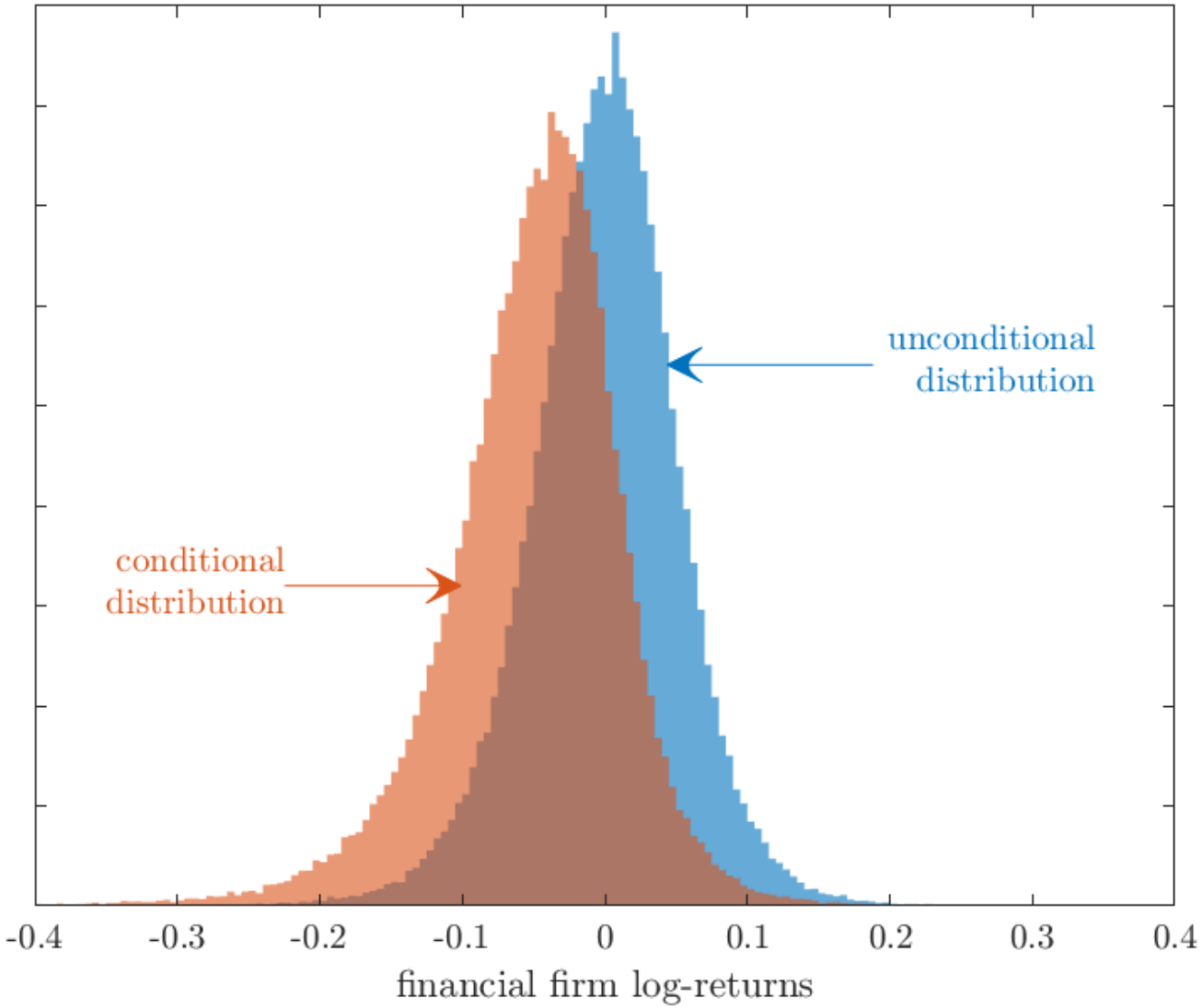
Orderly transition climate scenario



Hot house world climate scenario



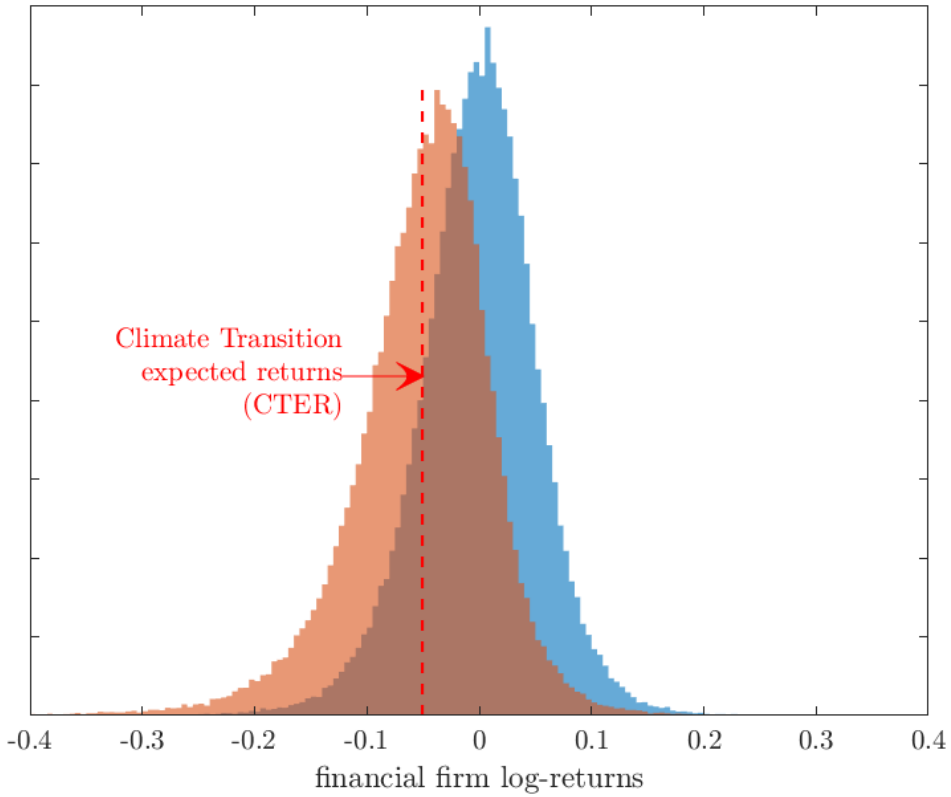
Building risk measures in climate scenarios



Building risk measures in climate scenarios

Climate Transition expected return (CTER) here

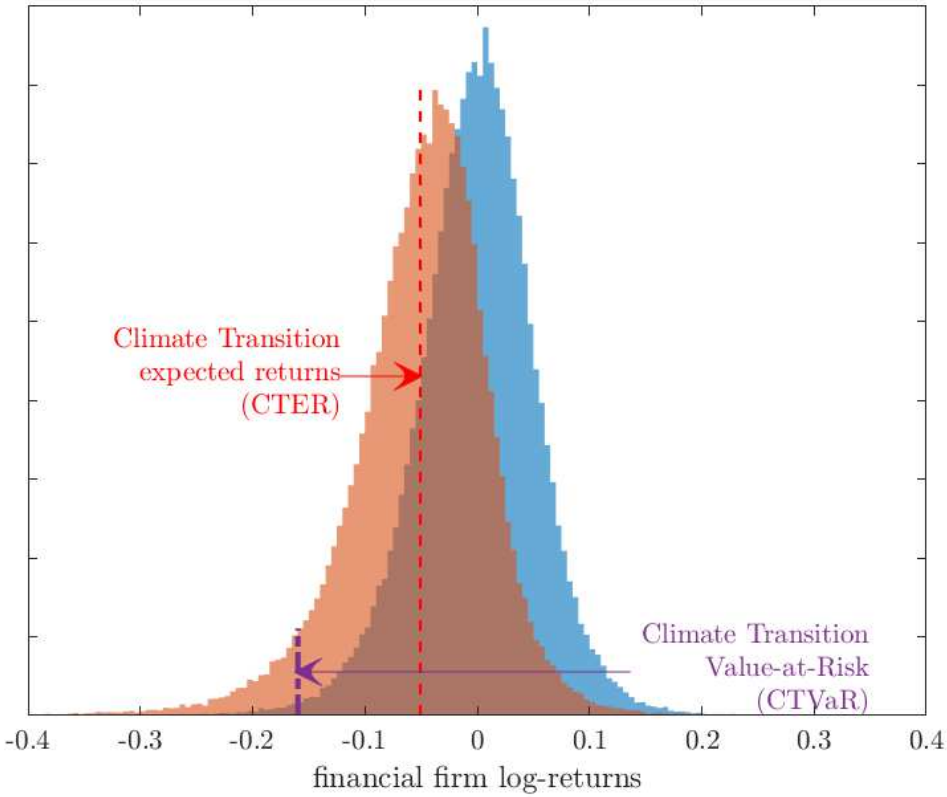
$$CTER_i = E(r_i | CT \quad scenario)$$



Building risk measures in climate scenarios

Climate Transition Value-at-Risk (CTVaR) here

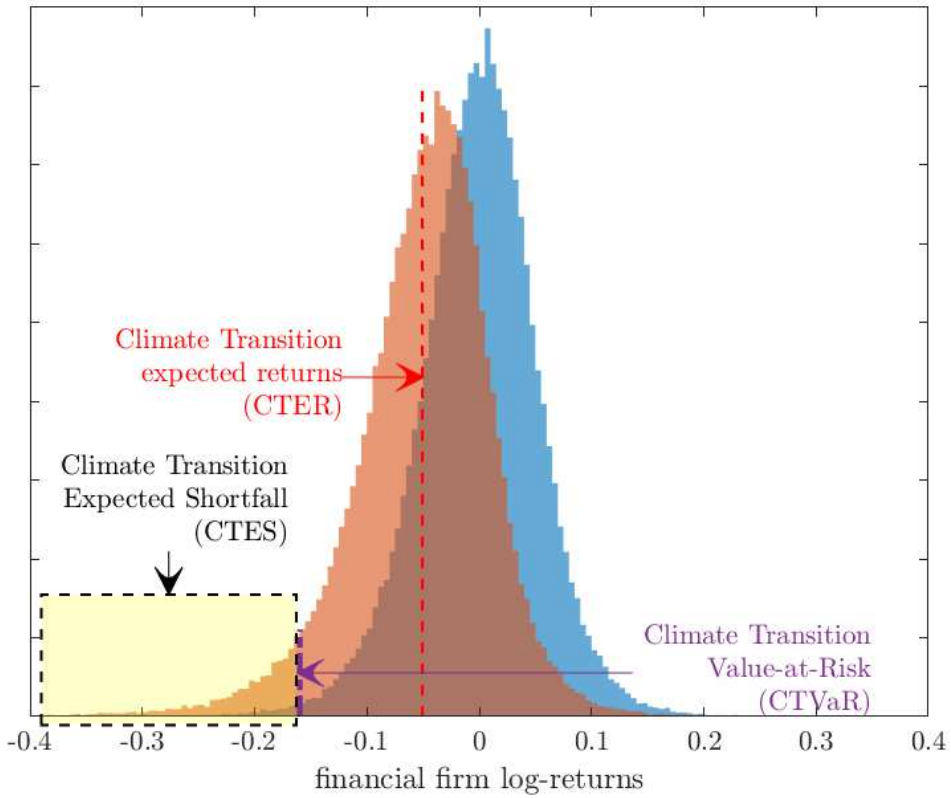
$$CTVaR_i = min\{r_i | F(r_i | CT \quad scenario) \geq \gamma\}$$



Building risk measures in climate scenarios

Climate Transition Expected Shortfall (CTES) here

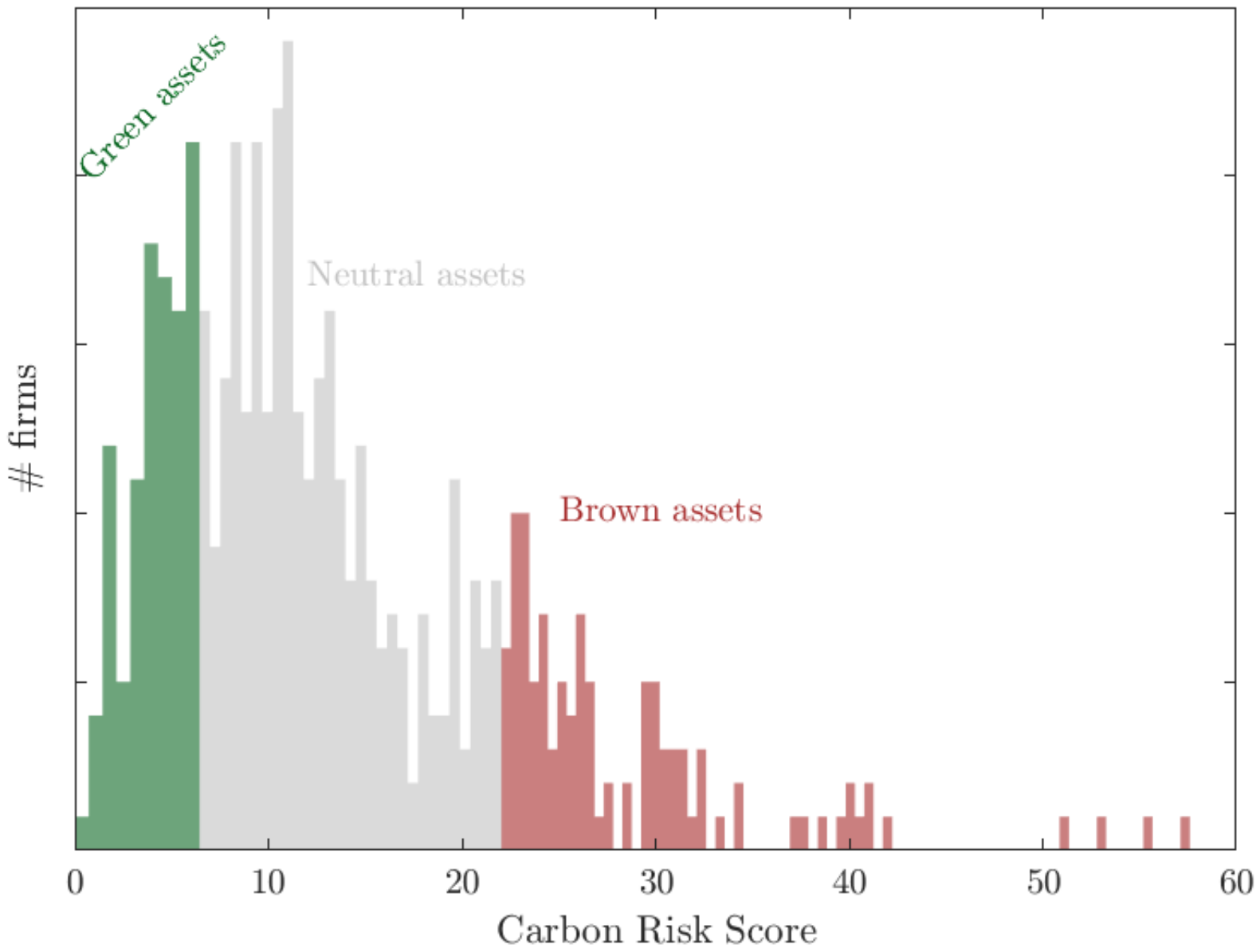
$$CTES_i = E(r_i | r_i < CTVaR_i, CT \quad scenario)$$



Overview

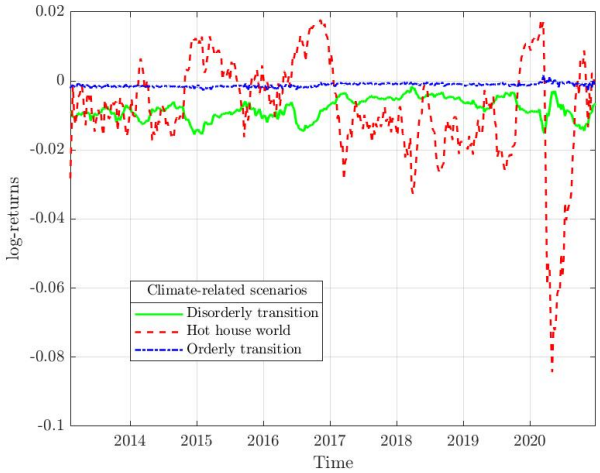
Data sample

- Period: 04 January 2013 to 25 December 2020 (417 obs.)
- Frequency: weekly
- Source: Bloomberg and Sustainalytics.
- 939 European listed firms
  - Employed to build the portfolios based on Carbon Risk Score (CRS)
  - CRS: employed by Morningstar to measure transition risk in fund portfolios.
- 190 European financial firms.
  - 22% banks, 19% insurance, 27% diversified financials, 31% real estate.
  - Countries: AT, BE, DK, FI, FR, DE, IE, IT, LU, NT, NO, PO, PT, ES, SE, CH, GB

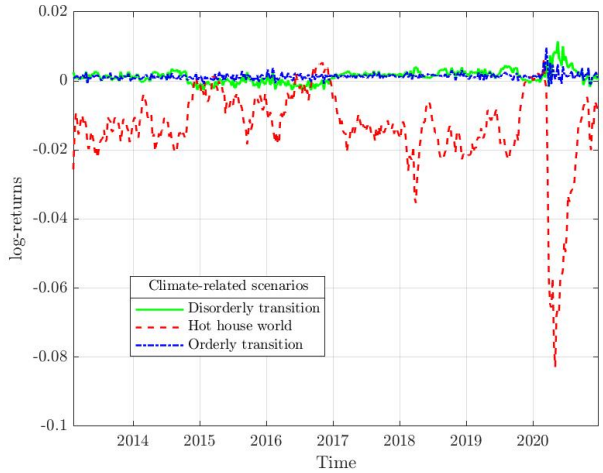

Green assets
Neutral assets
Brown assets
firms
0
10
20
30
40
50
60
Carbon Risk Score

Overview

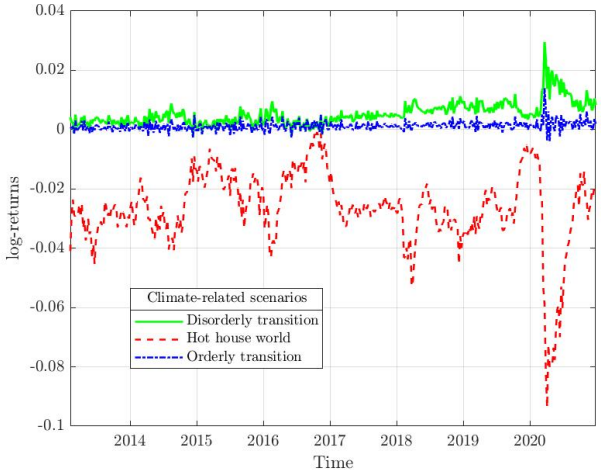
CT risk measures: CTER by sectors here



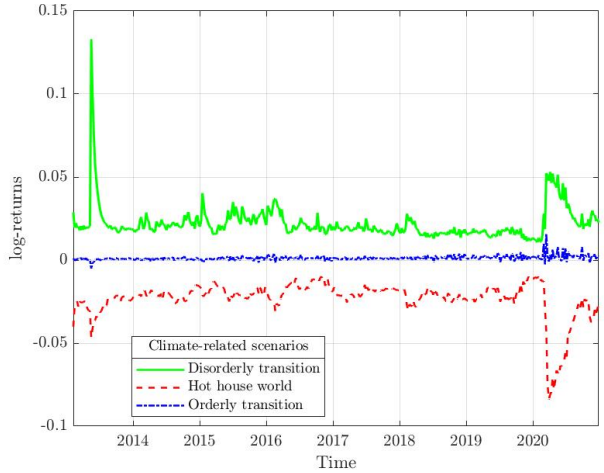
(a) Banks



(b) Insurance companies

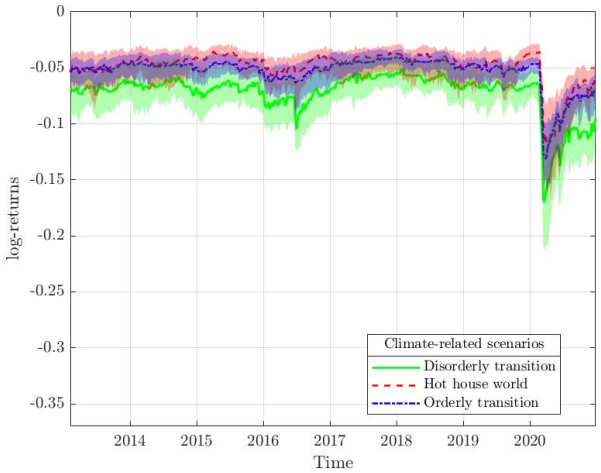


(c) Financial services



(d) Real estate

CT risk measures: CTVaR by sectors here



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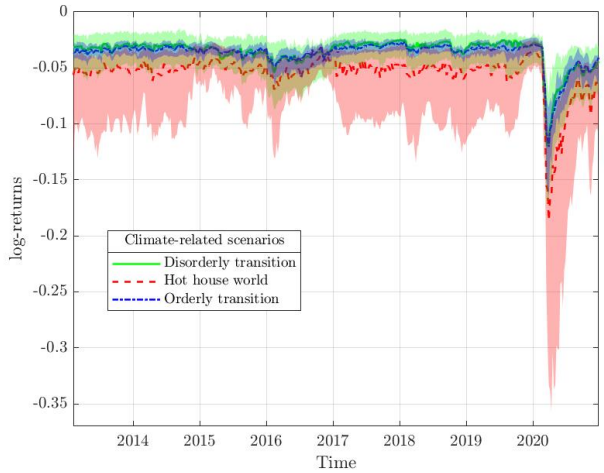

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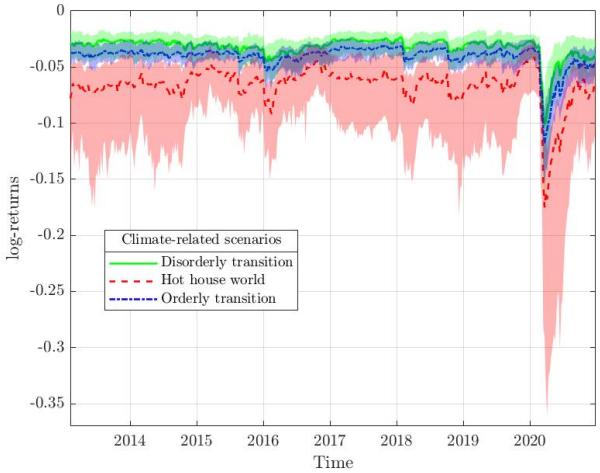

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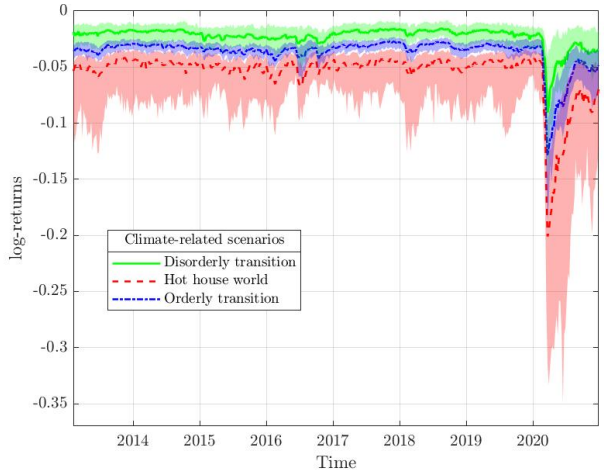

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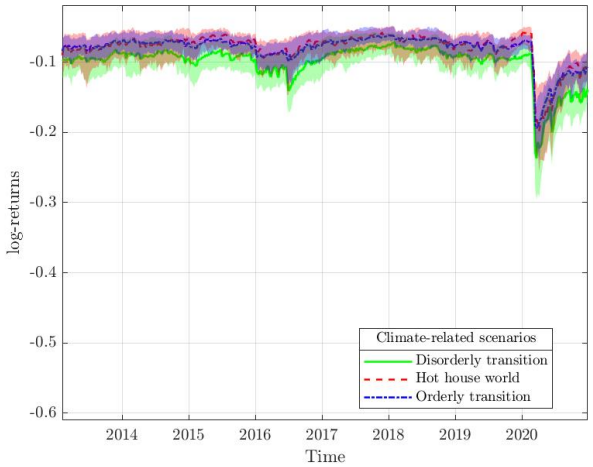

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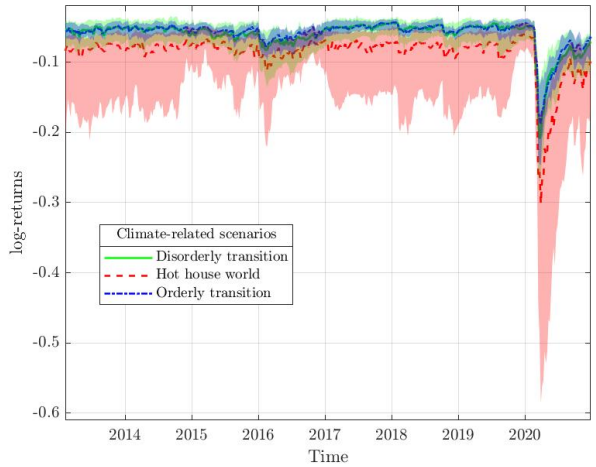

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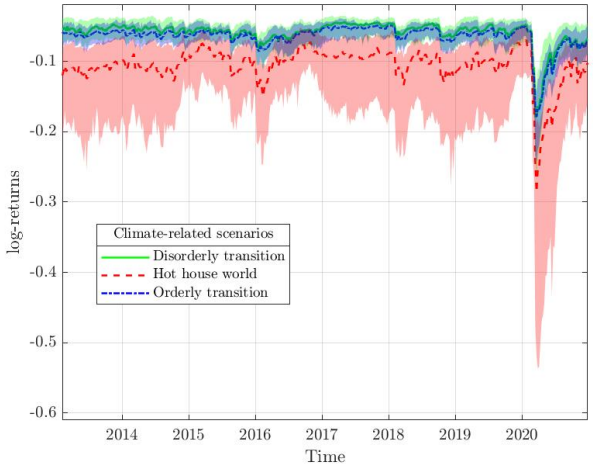

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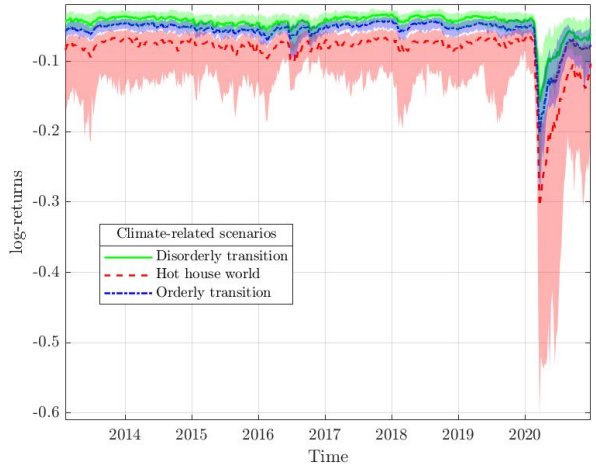


(d) Real estate

Climate transition expected returns: Countries

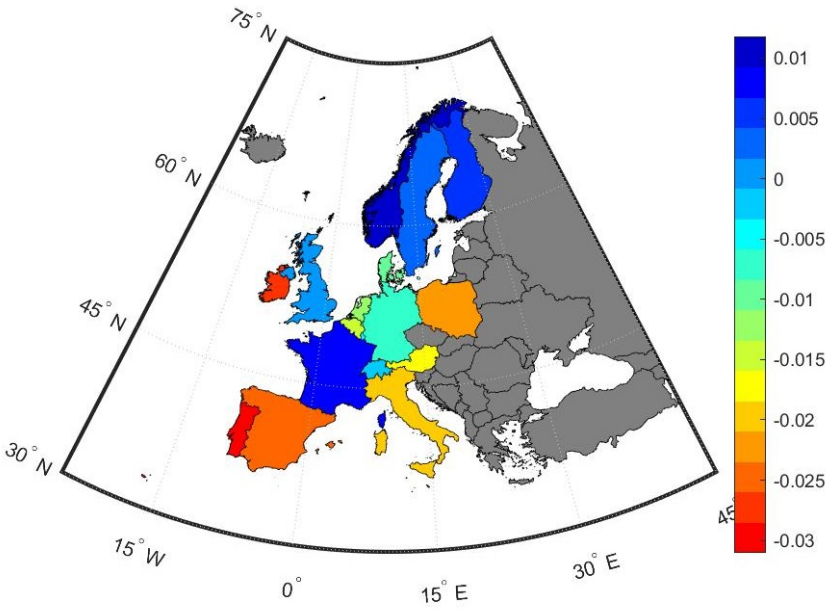


Figure: Disorderly transition

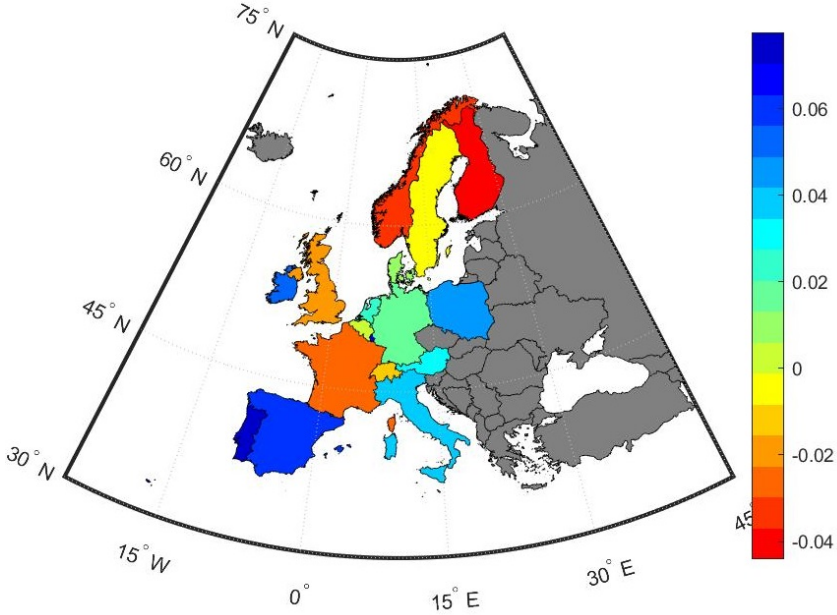


Figure: Hot house world

here

Climate transition risk: Implication for capital requirements

CTRISK

$$CTRISK_{i,t} = max\{0, CTCS_{i,t}\}$$

where:

$$CS = \underbrace{\overbrace{A}^{quasi-assets: A=D+W} k}_{\text{capital reserves}} - \overbrace{W}^{\text{market cap}}$$

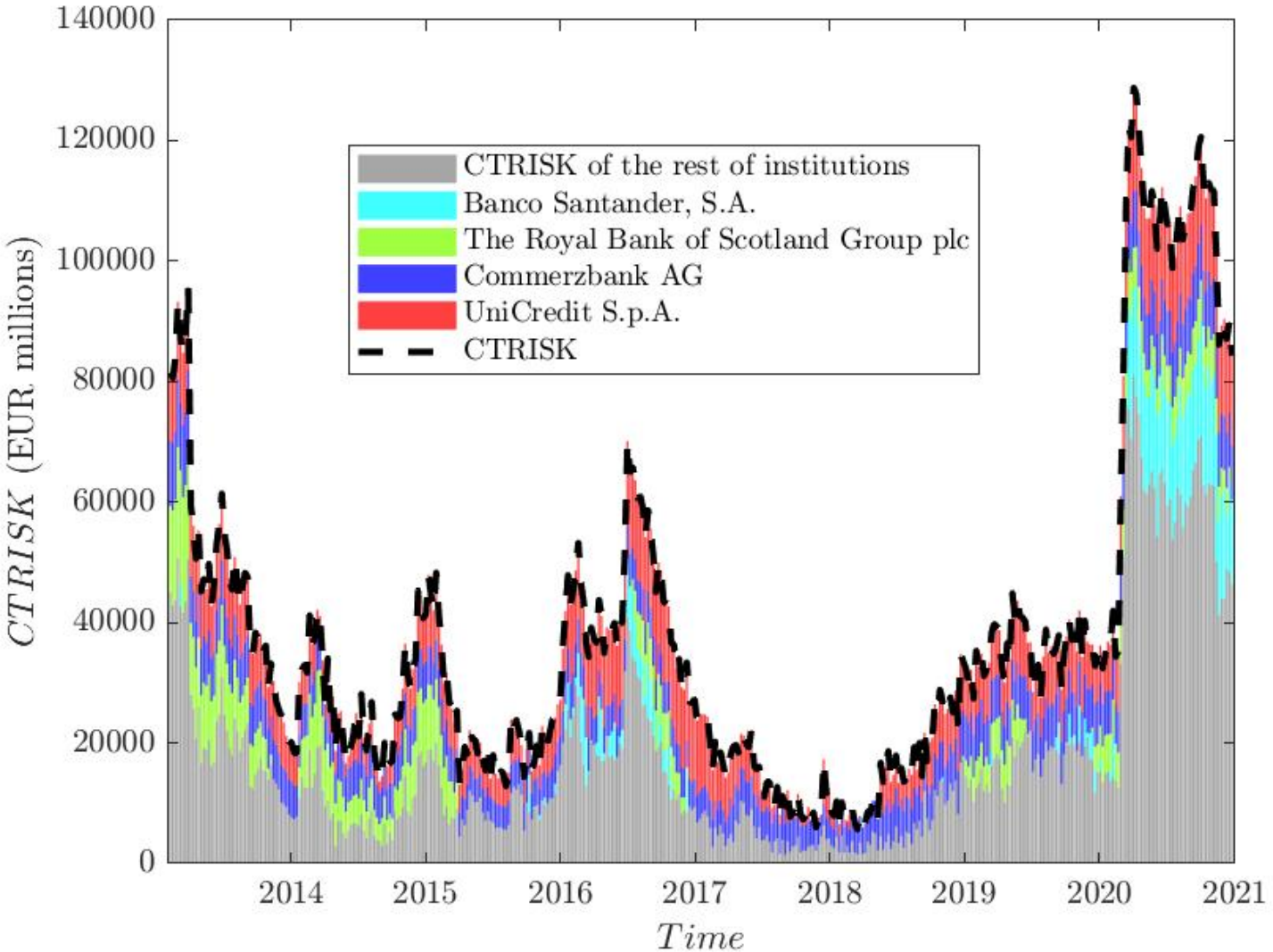
$$CTCS_{i,t} = E_t(CS_{t+h}|CT)$$

$$CTCS_{i,t} = kD_{i,t} - (1-k)\overbrace{(1+LRCTER_{i,t})W_{i,t}}^{E_t(W_{i,t+h}|CT)}$$

$$LRCTER_{i,t} = exp(52CTER_{i,t}) - 1$$

Climate expected capital shortfall for banks here

- Disorderly transition



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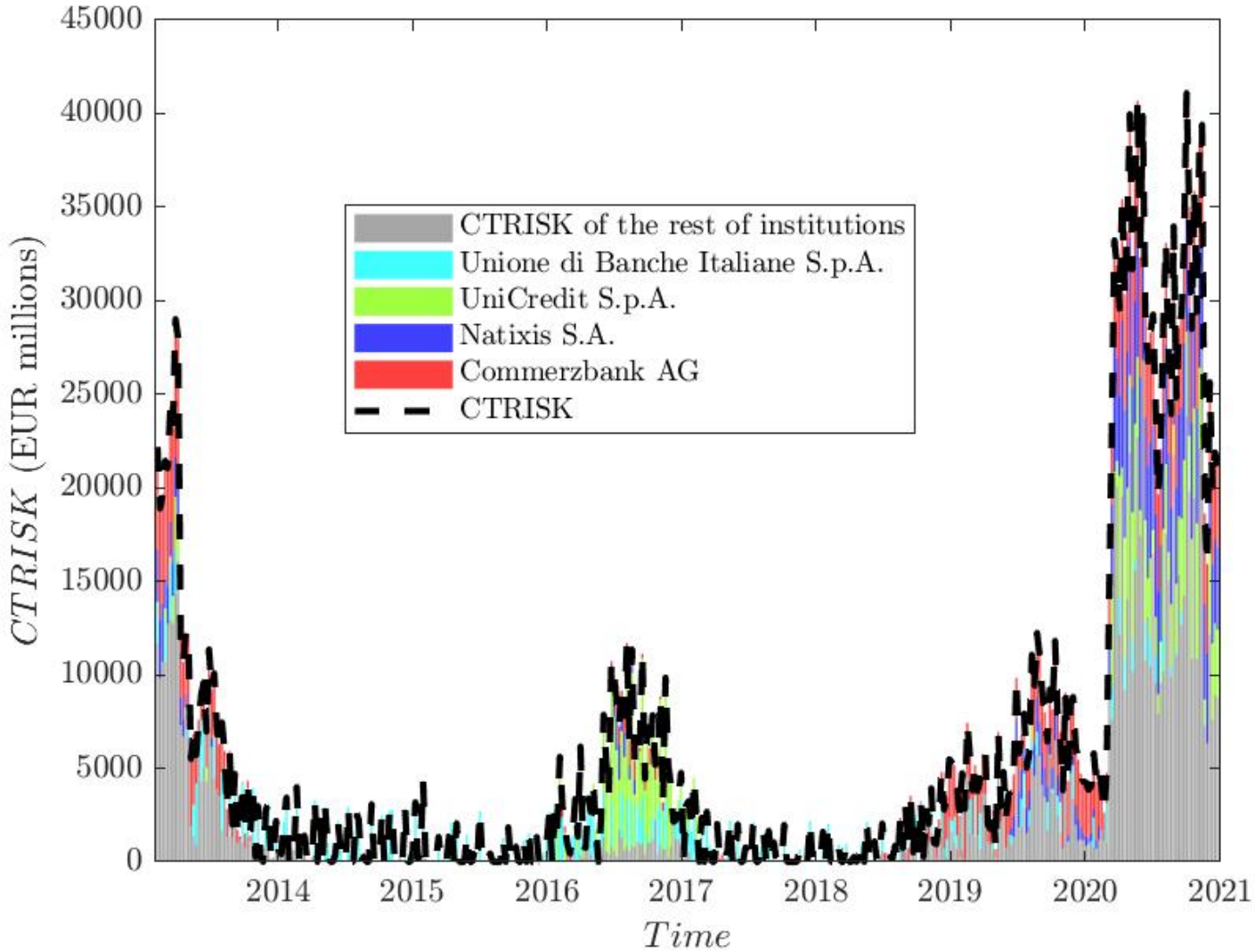
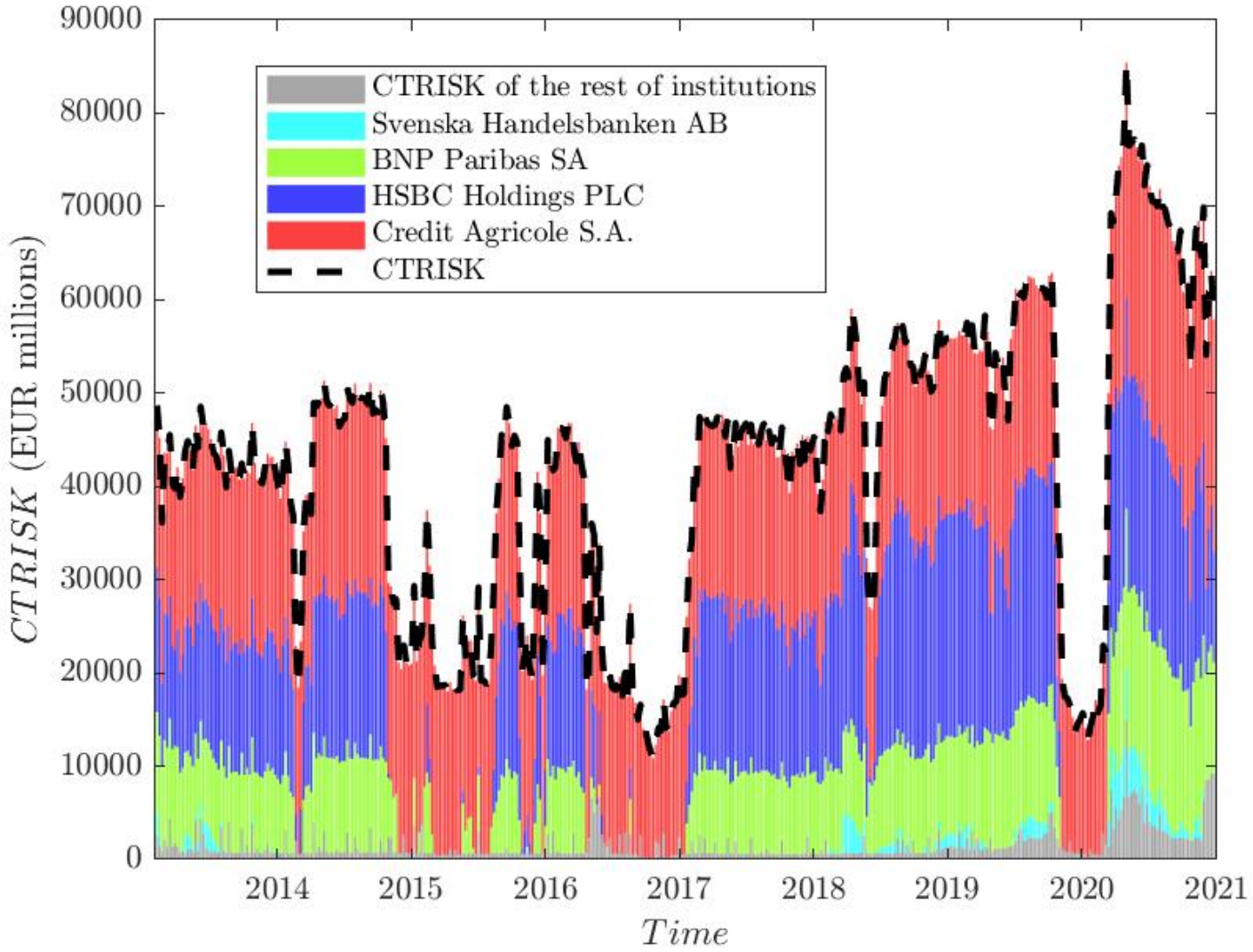
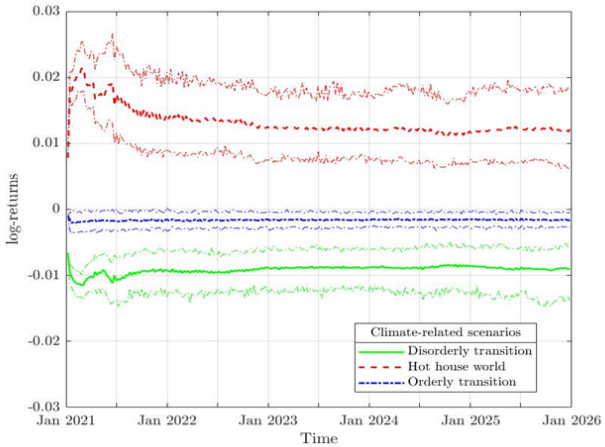


Climate expected capital shortfall for banks here

- Hot house world



Forward-looking simulation exercise: CTER



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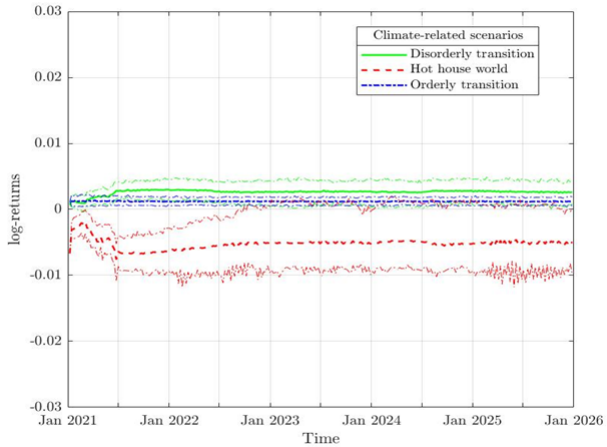

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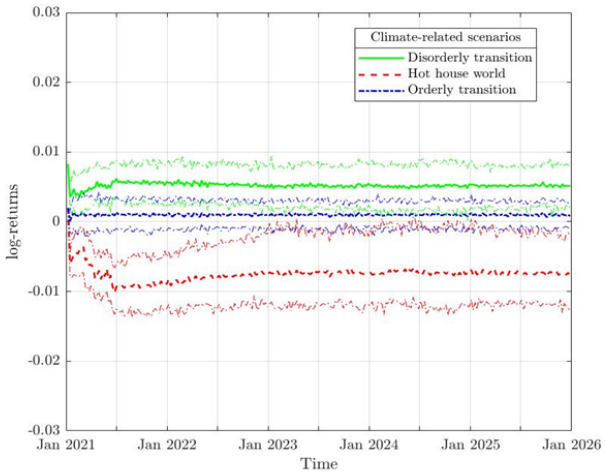

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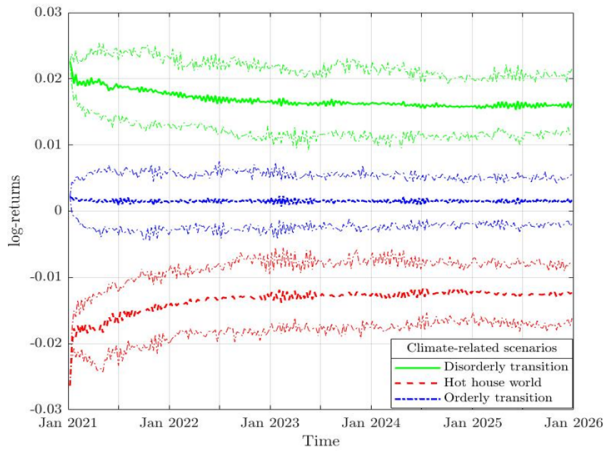


(d) Real estate

Overview

Goal

- We describe an empirical setup to quantify systemic impact of climate transition risk on financial firms.
- We translate climate scenarios into systemic risk measures well-known by the industry. Also, we study the implications for capital shortfall in the European financial system.
- We forecast climate transition measures for the next five-year period.
- We define different scenarios using public available data and employing an easily replicable methodology. This implies a considerable improvement with respect to other methodologies dealing with this topic ([Dietz et al., 2016], [Jung et al., 2021], [Battiston et al., 2017])

Findings

- Banks are negative exposed to a disorderly transition scenario while the remainder sectors are mainly exposed to a hot house world scenario.
- There is a large heterogeneity in the cross-section performance of risk measures, specially for the non-banking system in the hot house world scenario.
- Spain, Portugal, Ireland and Poland are the countries that experience the largest financial losses in a disorderly transition scenario. United Kingdom, France, Norway and Finland obtain the largest financial losses in a hot house world scenario.
- Capital needs are led by different firms depending on the scenario, while being manageable by the financial system.
- In the next five years, banks may be at a significant disadvantage in a disorderly transition scenario, while non-banking sectors are likely to experience large systemic risk effects in a hot house world scenario.

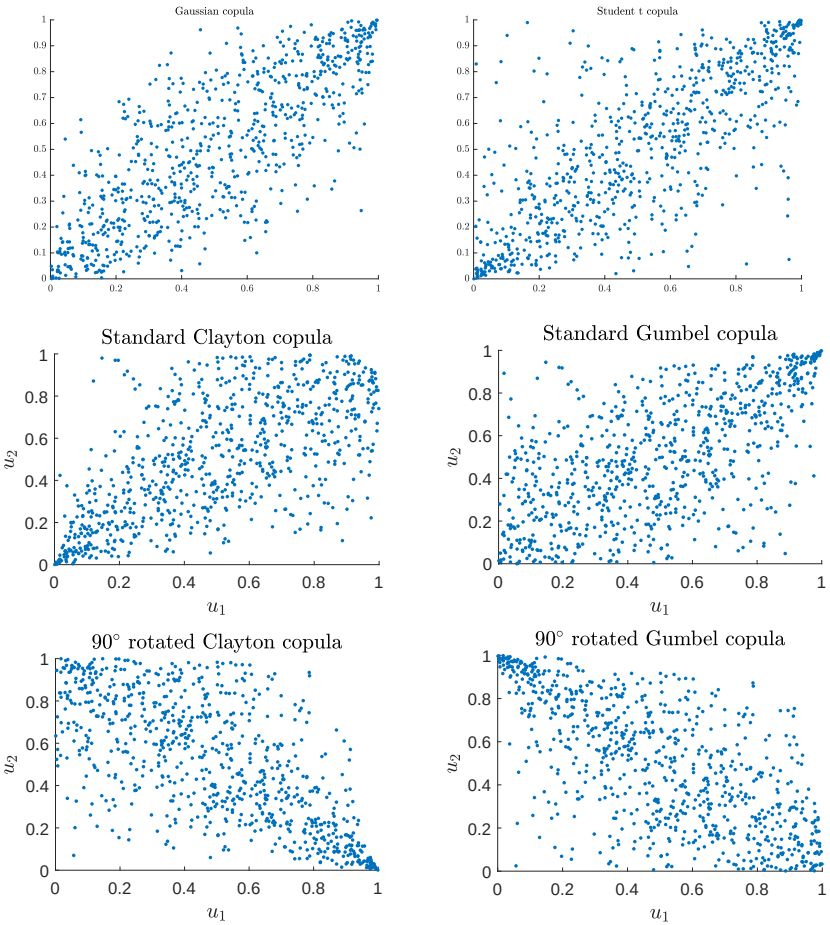
Thank you very much.

Appendix

Appendix

Copula features

Copula	Association	Tail dependenc
Gaussian	+ / -	No
Student t	+ / -	Symmetric
Clayton	+	Lower
Gumbel	+	Upper
BB1	+	Asymmetric
90° Clayton	-	Lower
90° Gumbel	-	Upper
90° BB1	-	Asymmetric



Main presentation

Dynamics over time following [Patton, 2006] specification

Elliptic copulas	$\rho_t = \Delta(\psi_0 + \psi_1 \rho_{t-1} + \psi_2 1/q \sum_{j=1}^{q} \Phi^{-1}(u_{t-j}) \Phi^{-1}(v_{t-j}))$
Non-elliptic copulas	$\theta_t = \Delta(\omega + \beta \theta_{t-1} + \alpha 1/q \sum_{j=1}^{q} \lvert u_{t-j} - v_{t-j} \rvert)$

	$\Delta(\dots)$
Gaussian **Student**	$(1 - exp(-x))/(1 + exp(-x))$
Clayton	$100/(1 + exp(-x))$
Gumbel	$1 + 99/(1 + exp(-x))$
BB1	$1/(1 + exp(-x))$

Main presentation

Appendix

Vine structure

- Building the joint density distribution by recursive factorization

$$f(r_g, r_n, r_b) = f(r_n) f(r_g|r_n) f(r_b|r_n, r_g)$$

- Using Bayes' theorem

$$f(r_g, r_n, r_b) = f(r_n) \frac{f(r_g, r_n)}{f(r_n)} \frac{f(r_g, r_b|r_n)}{f(r_g|r_n)}$$

Main presentation

Vine structure

- Building the joint density distribution by recursive factorization

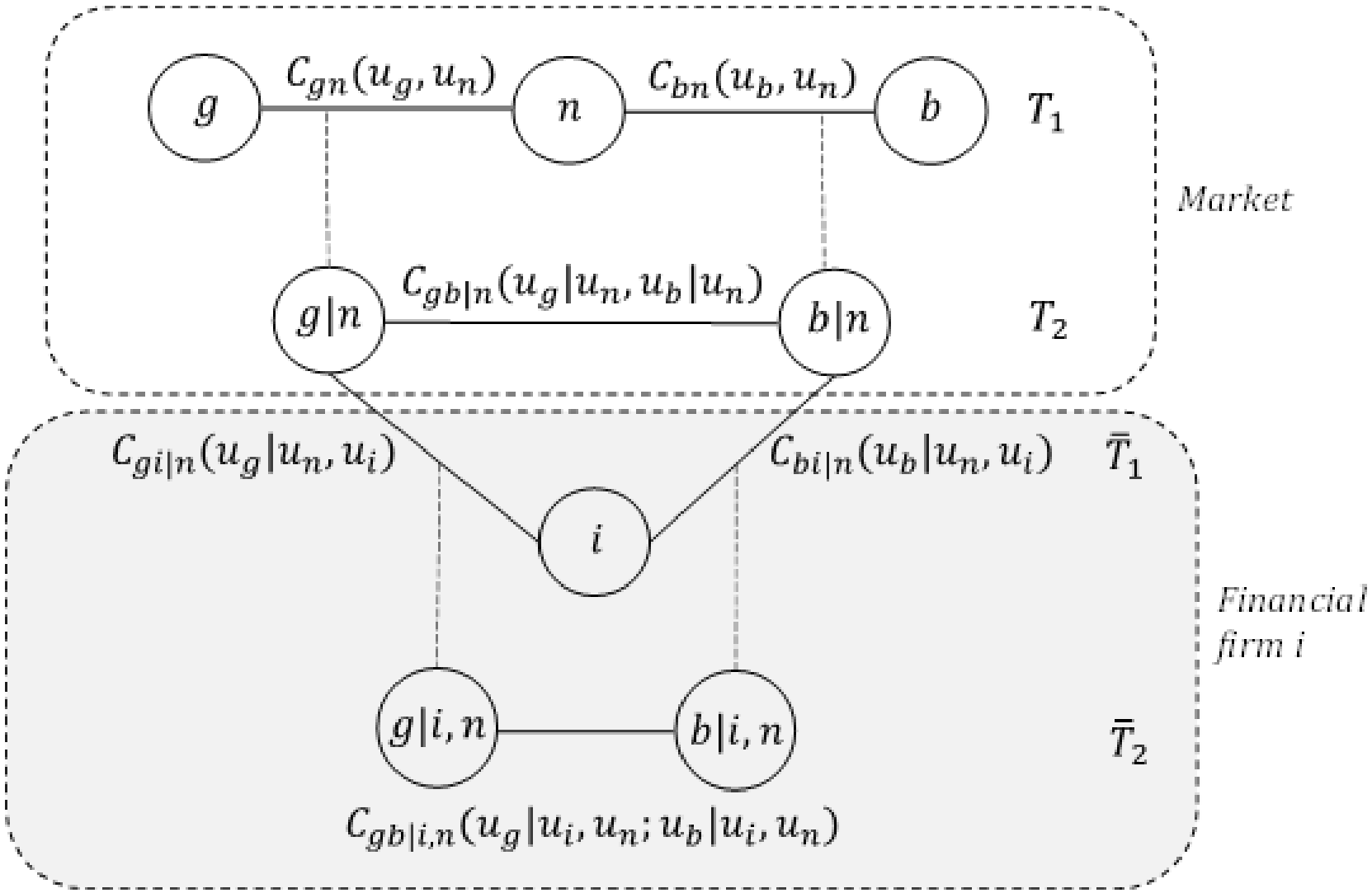
$$f(r_g, r_n, r_b) = f(r_n) f(r_g|r_n) f(r_b|r_n, r_g)$$

- In terms of copulas

$$\begin{aligned} f(r_g, r_n, r_b) &= f(r_n) f(r_b) f(r_g) c(F(r_n), F(r_g)) \\ & \quad c(F(r_n), F(r_b)) c(F(r_b|r_n), F(r_g|r_n)) \end{aligned}$$

Main presentation

Vine structure



Main presentation

Appendix

Climate transition expected returns (CTER) Main presentation

$$E(r_i|r_g \geq q_g^\beta, r_b \leq q_b^\alpha) = \int_{-\infty}^{\infty} r_i f(r_i|r_g \geq q_g^\beta, r_b \leq_b^\alpha) dr_i$$

$$= \frac{1}{P(r_g \geq q_g^\beta, r_b \leq q_b^\alpha)} \int_{-\infty}^{\infty} r_i f(r_i, r_g \geq q_g^\beta, r_b \leq q_b^\alpha) dr_i$$

where

$$P(r_g \geq q_g^\beta, r_b \leq q_b^\alpha) = P(r_b \leq q_b^\alpha) - P(r_g \leq q_g^\beta, r_b \leq q_b^\alpha),$$

$$P(r_g \geq q_g^\beta, r_b \leq q_b^\alpha) = \int_0^1 \left(C_{b|n}(\alpha|u_n) - C_{b,g|n}(C_{b|n}(\alpha|u_n), C_{g|n}(1-\beta|u_n))\right) du_n$$

and

$$f(r_i, r_g \geq q_g^\beta, r_b \leq q_b^\alpha) = \int_0^1 \left(C_{b|i,n}(C_{b|n}(\alpha|u_n)|u_i) - \right.$$

$$\left. C_{b,g|n,i}(C_{b|i,n}(C_{b|n}(\alpha|u_n)|u_i), C_{g|i,n}(C_{g|n}(1-\beta|u_n)|u_i))\right) f_i(F_i^{-1}(u_i)) du_n$$

Climate transition value-at-risk (CTVaR)

Main presentation

$$CTVaR_i^{\gamma} = min\left[r_i | P(r_i \leq CTVaR_i^{\gamma} | r_g \geq q_g^{\beta}, r_b \leq q_b^{\alpha}) \geq \gamma\right]$$

where

$$\begin{aligned} P(r_i \leq CTVaR_i^{\gamma} | r_g \geq q_g^{\beta}, r_b \leq q_b^{\alpha}) &= \gamma \\ &= \frac{P(CTVaR_i^{\gamma}, r_g \geq q_g^{\beta}, r_b \leq q_b^{\alpha})}{P(r_g \geq q_g^{\beta}, r_b \leq q_b^{\alpha})} \end{aligned}$$

and

$$P(CTVaR_i^{\gamma}, r_g \geq q_g^{\beta}, r_b \leq q_b^{\alpha}) = \int_0^{F_i(CTVaR_i^{\gamma})} \int_0^1 \left(C_{b|n,i}(C_{b|n}(\alpha|u_n)|u_i) - C_{g,b|i,n}\left(C_{b|n,i}(C_{b|n}(\alpha|u_n)|u_i), C_{g|n,i}(C_{g|n}(1-\beta|u_n)|u_i)\right)\right) du_n du_i$$

Climate transition expected shortfall (CTES)

Main presentation

$$E(r_i|r_g \geq q_g^\beta, r_b \leq q_b^\alpha, r_i \leq CTVaR_i^\gamma) = \int_{-\infty}^{CTVaR_i^\gamma} r_i f(r_i|r_g \geq q_g^\beta, r_b \leq_b^\alpha, r_i \leq CTVaR_i^\gamma) dr_i$$

$$= \frac{1}{P(r_g \geq q_g^\beta, r_b \leq q_b^\alpha, r_i \leq CTVaR_i^\gamma)} \int_{-\infty}^{CTVaR_i^\gamma} r_i f(r_i, r_g \geq q_g^\beta, r_b \leq q_b^\alpha) dr_i$$

where

$$P(r_g \geq q_g^\beta, r_b \leq q_b^\alpha, r_i \leq CTVaR_i^\gamma) = P(r_b \leq q_b^\alpha, r_i \leq CTVaR_i^\gamma) -$$
$$P(r_g \leq q_g^\beta, r_b \leq q_b^\alpha, r_i \leq CTVaR_i^\gamma), P(r_g \geq q_g^\beta, r_b \leq q_b^\alpha) =$$
$$\int_0^{F_i(CTVaR_i^\gamma)} \int_0^1 \left(C_{b|i}(C_{b|n}(\alpha|u_n)|u_i) - \right.$$
$$\left. C_{b,g|n,i}(C_{b|i}(C_{b|n}(\alpha|u_n)|u_i), C_{g|i}(C_{g|n}(1-\beta|u_n)|u_i))\right) du_n du_i$$

and

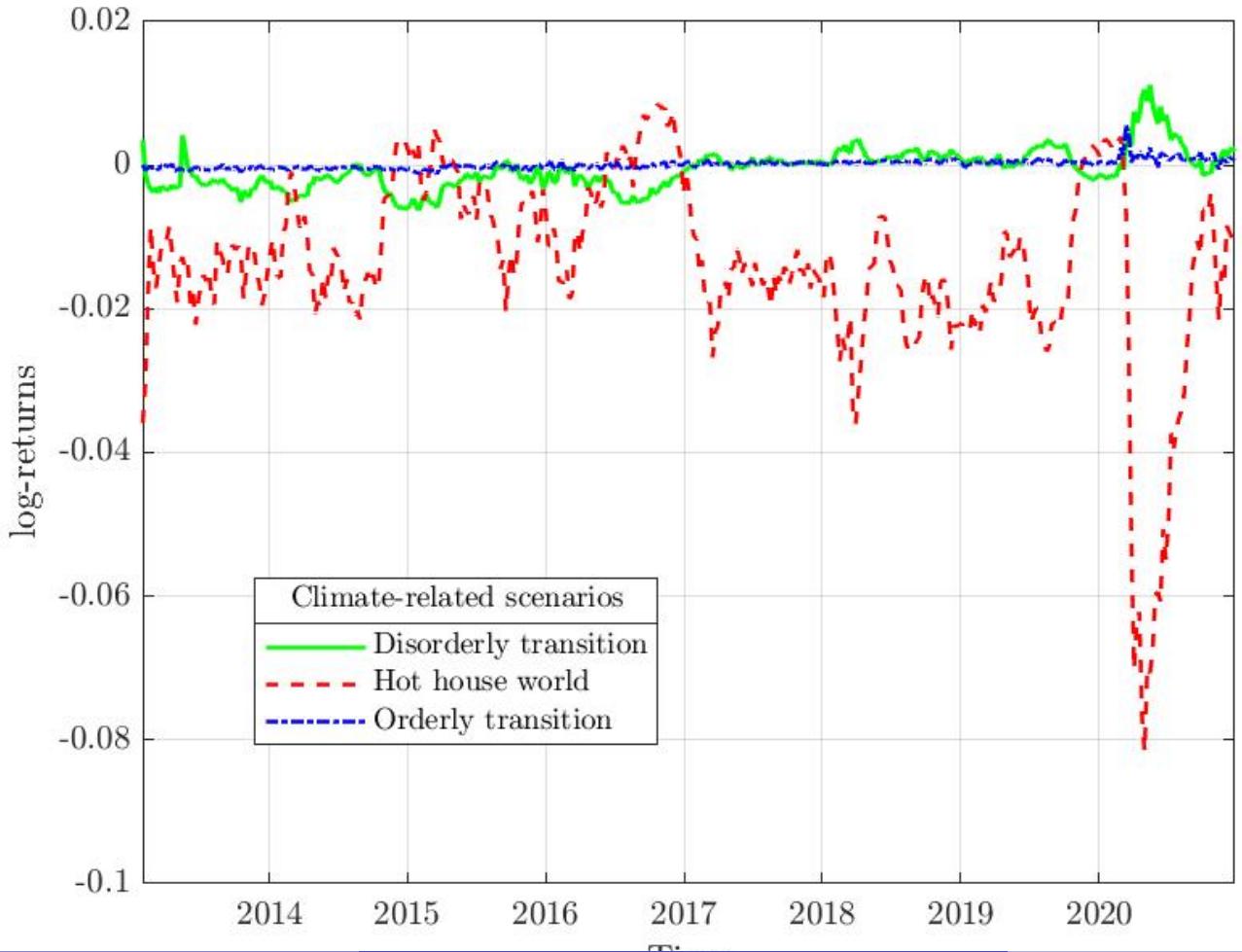
$$f(r_i, r_g \geq q_g^\beta, r_b \leq q_b^\alpha) = \int_0^1 \left(C_{b|i,n}(C_{b|n}(\alpha|u_n)|u_i) - \right.$$
$$\left. C_{b,g|n,i}(C_{b|i,n}(C_{b|n}(\alpha|u_n)|u_i), C_{g|i,n}(C_{g|n}(1-\beta|u_n)|u_i))\right) f_i(F_i^{-1}(u_i)) du_n$$

Appendix

Climate transition risk measures: financial system

Main presentation

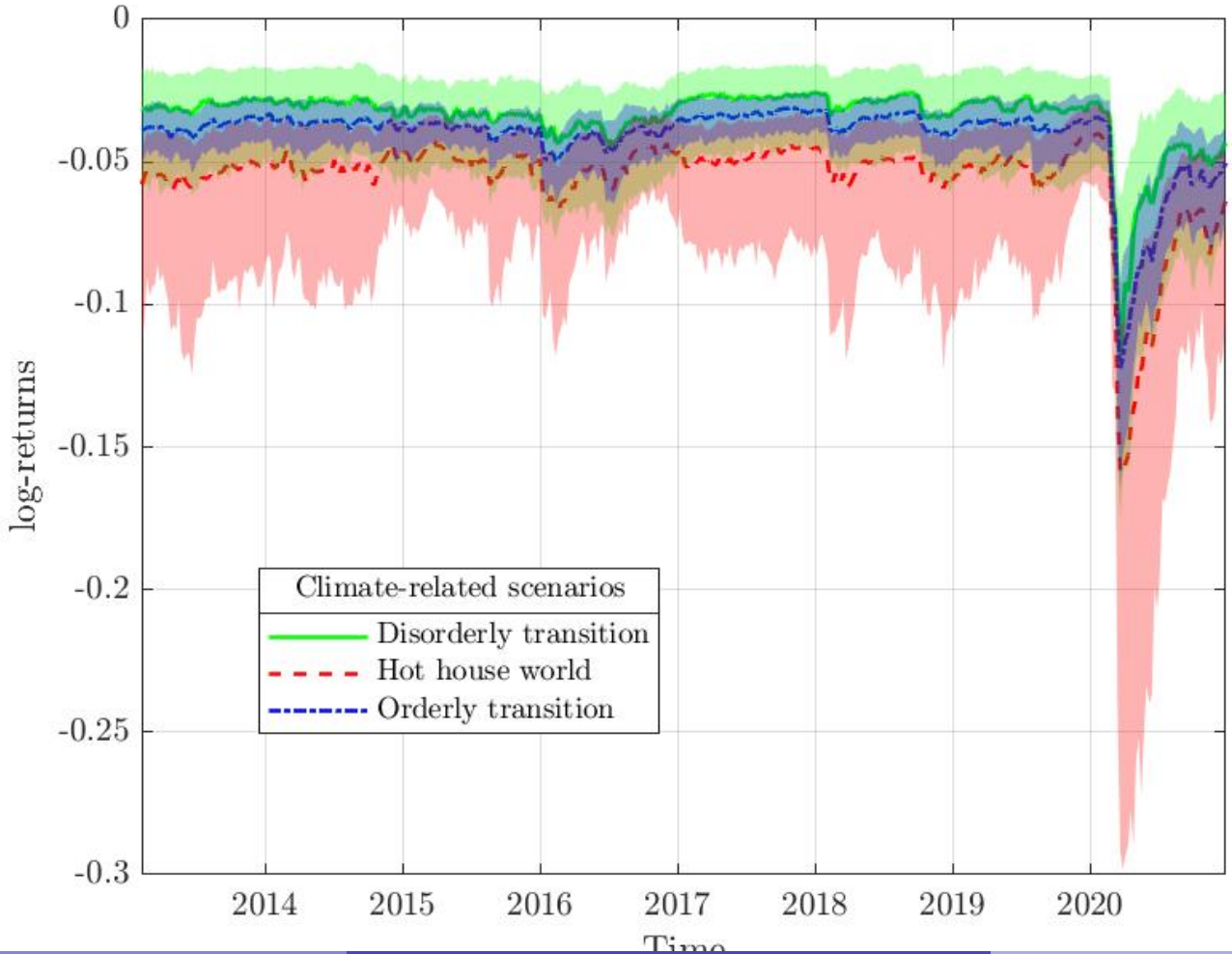
- Climate Transition expected returns



Climate transition risk measures: financial system

Main presentation

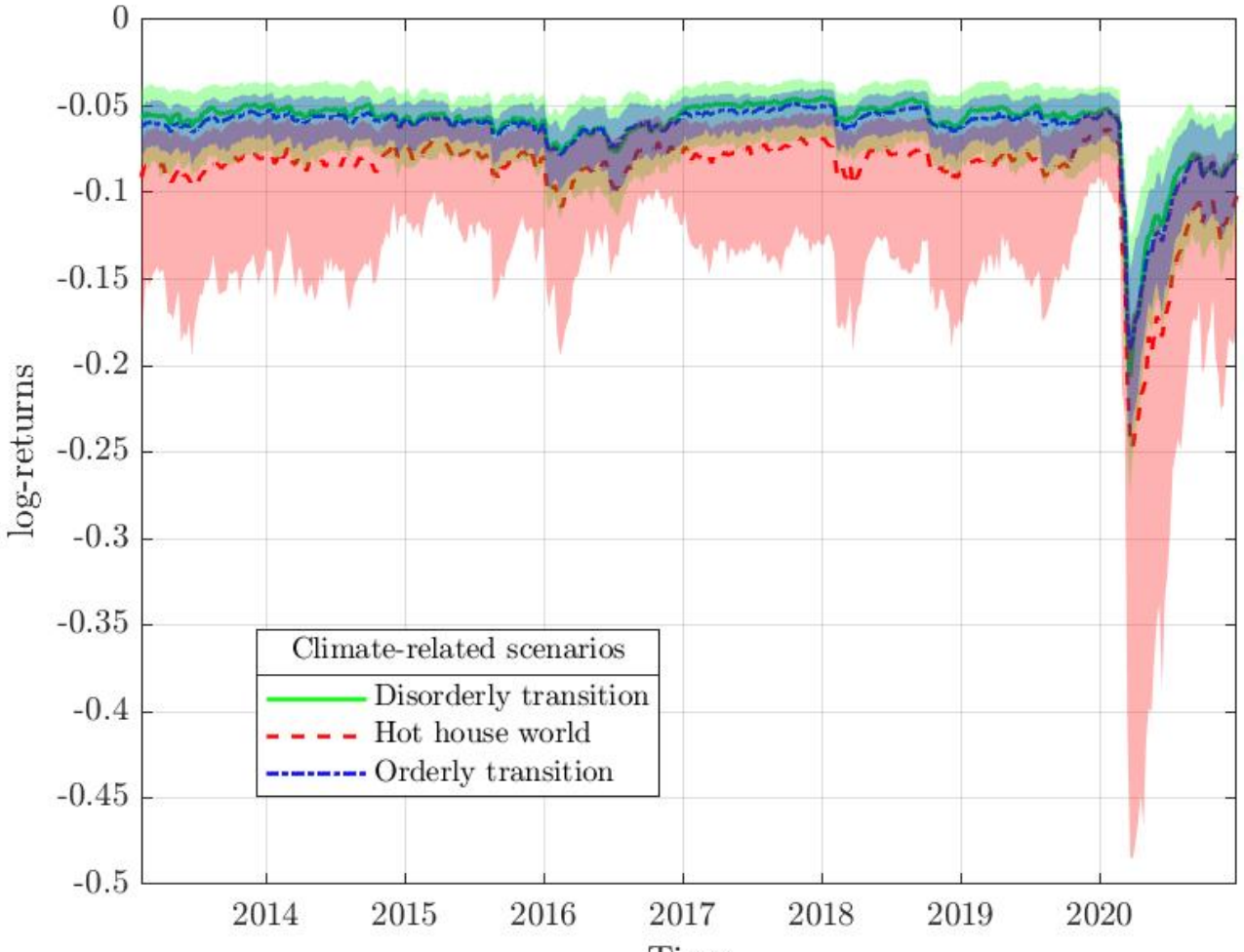
- Climate Transition Value-at-Risk



Climate transition risk measures: financial system

Main presentation

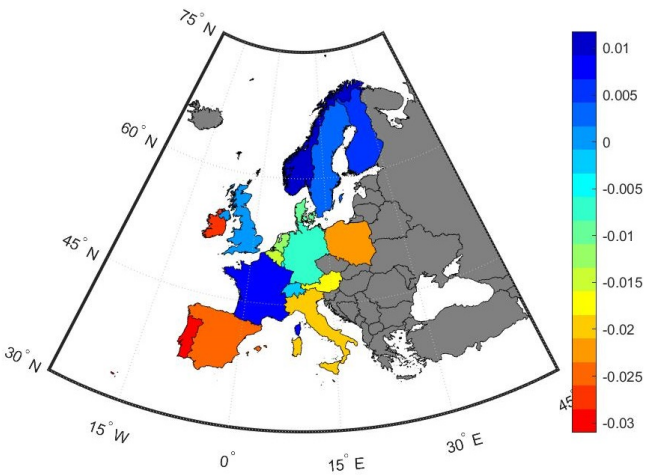
- Climate Transition Expected Shortfall



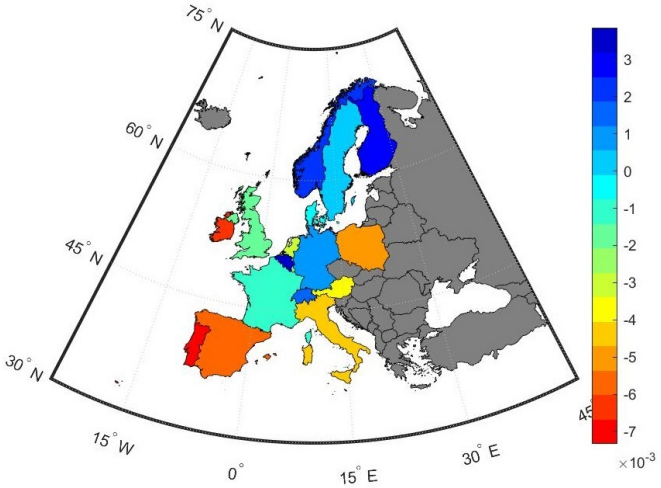
Appendix

CTER by country under different climate scenarios

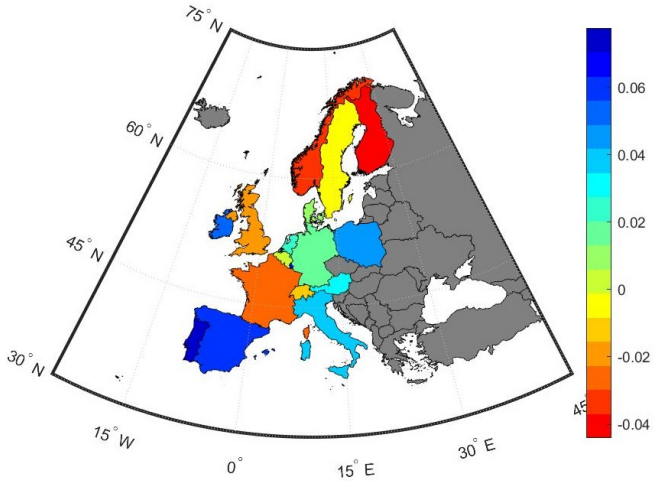
- Disorderly transition



- Orderly transition



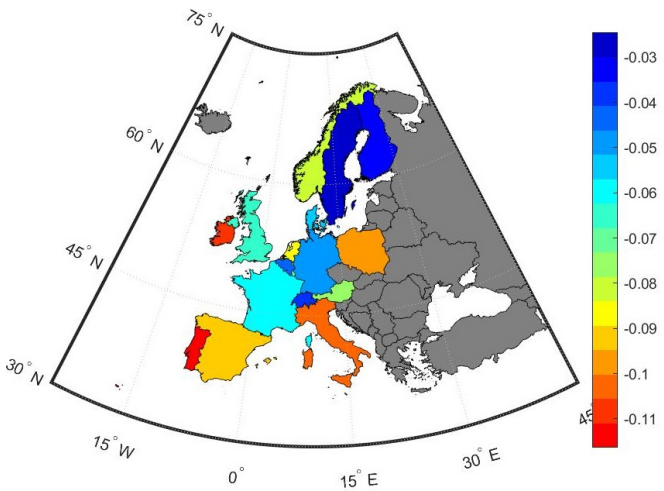
- Hot house world



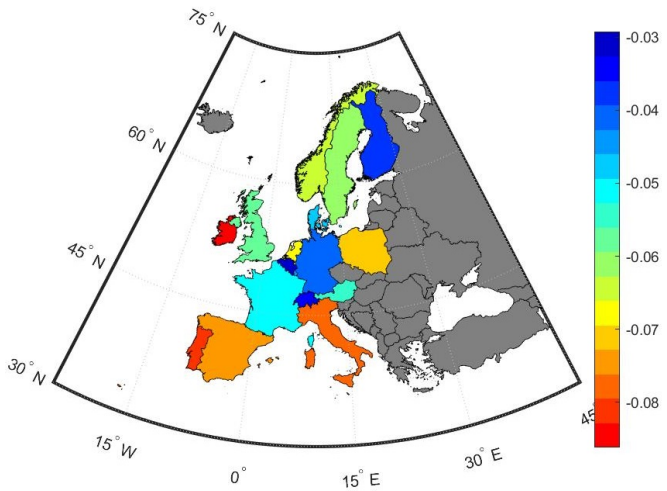
Main presentation

CTVaR by country under different climate scenarios

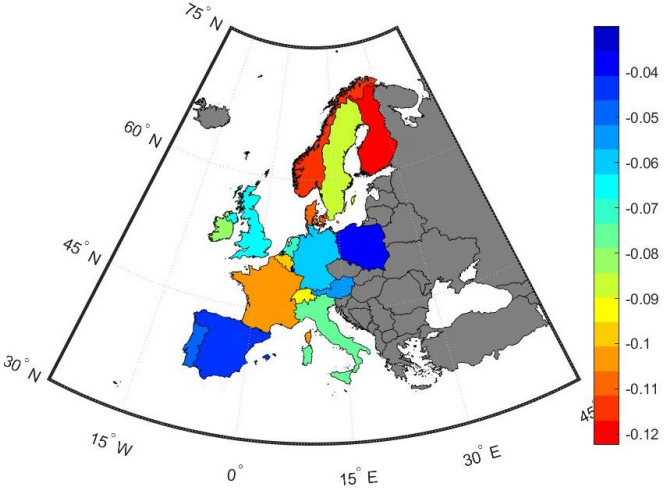
- Disorderly transition



- Orderly transition



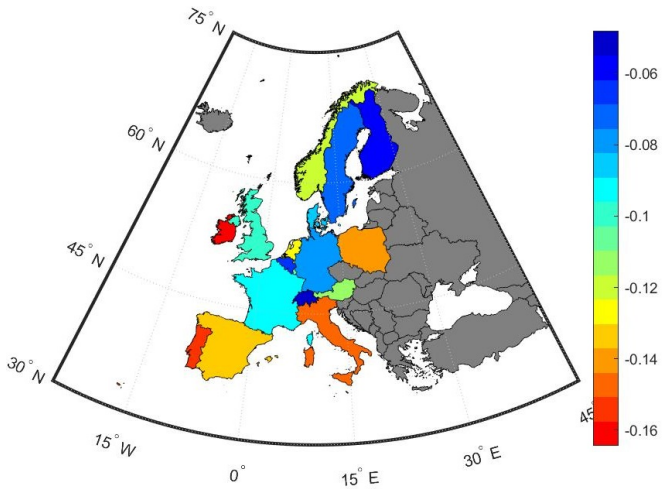
- Hot house world



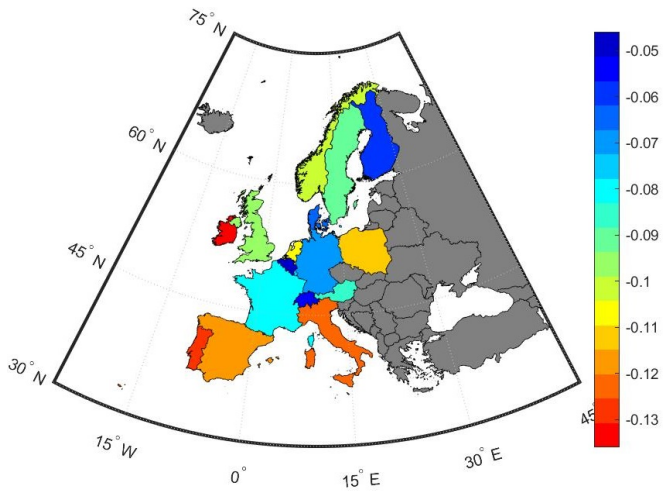
Main presentation

CTES by country under different climate scenarios

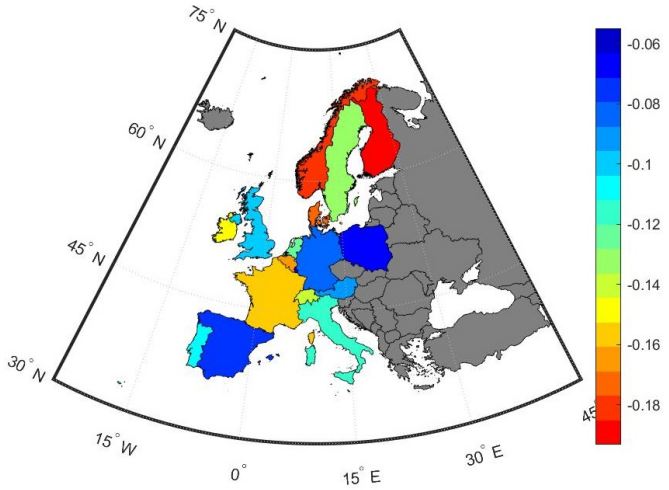
- Disorderly transition



- Orderly transition



- Hot house world

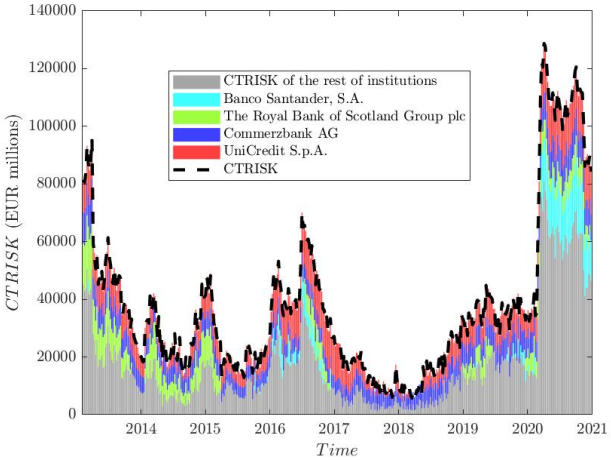


Main presentation

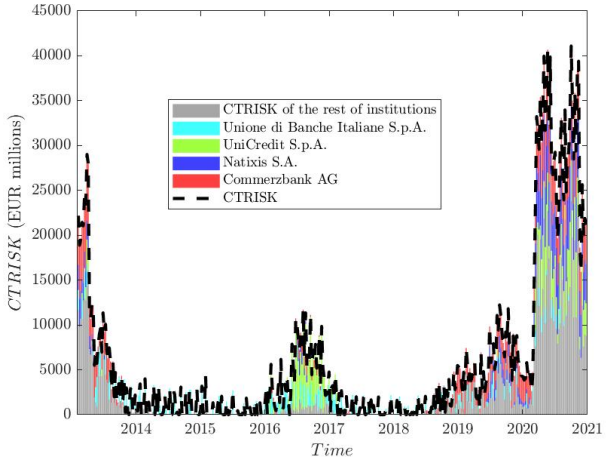
Appendix

CTRISK by sector: banks

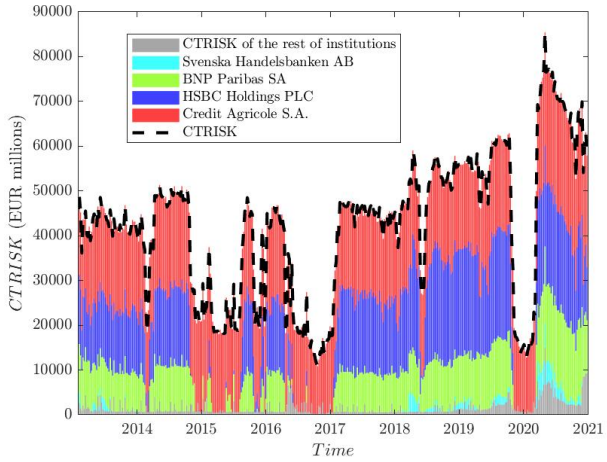
- Disorderly transition



- Orderly transition



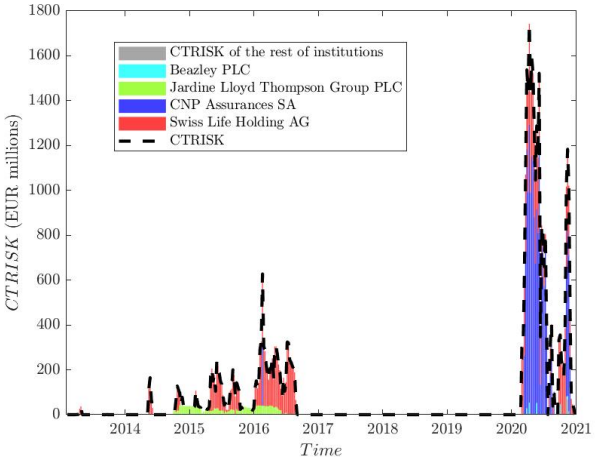
- Hot house world



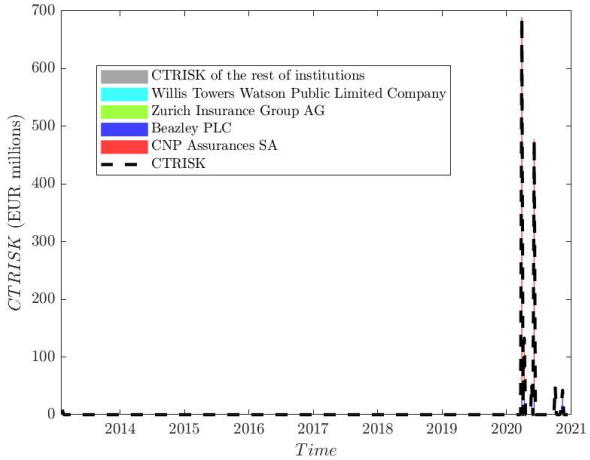
Main presentation

CTRISK by sector: insurance

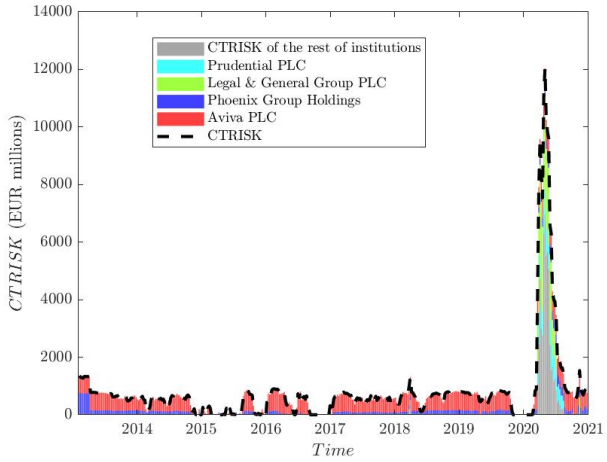
- Disorderly transition



- Orderly transition



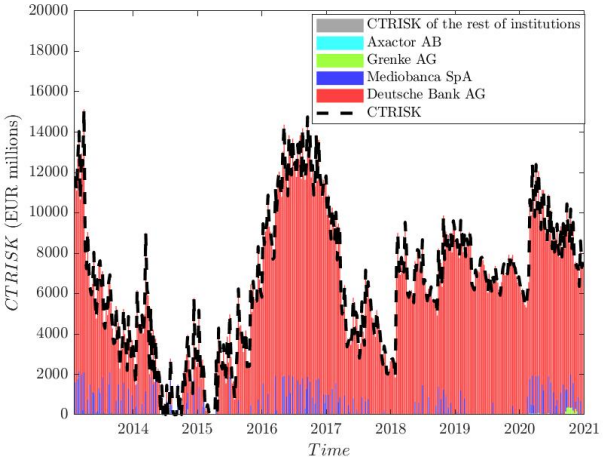
- Hot house world

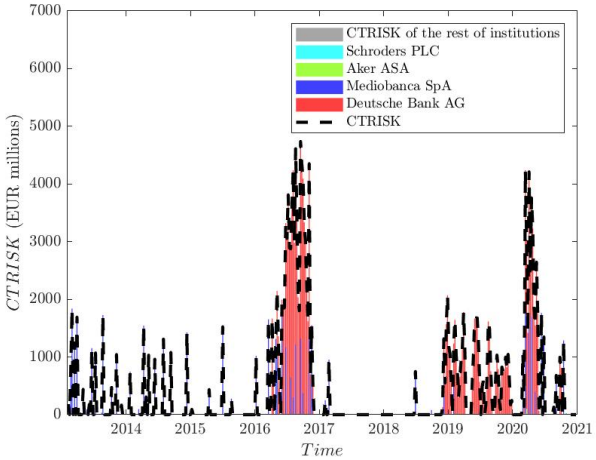


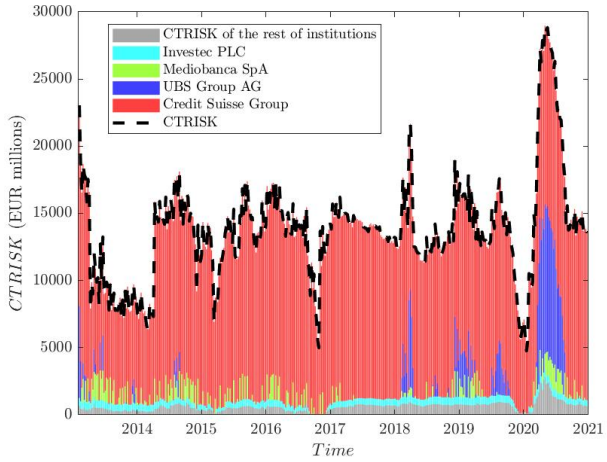
Main presentation

CTRISK by sector: diversified financial

- Disorderly transition
- Orderly transition
- Hot house world



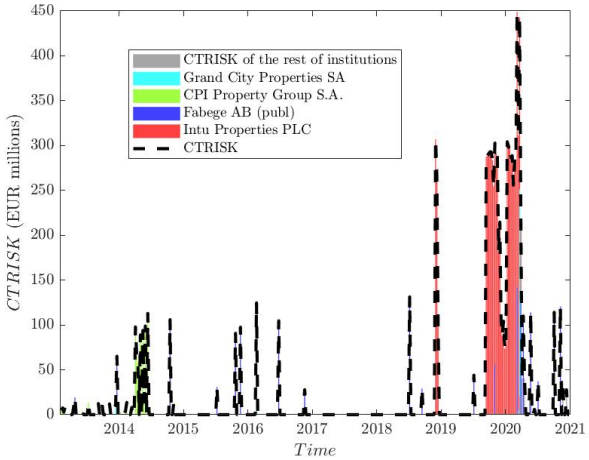




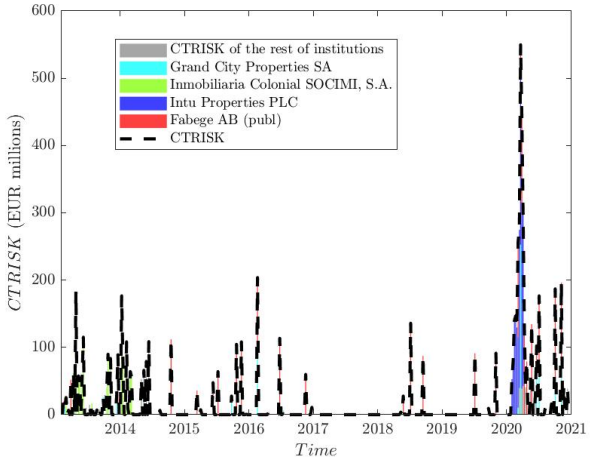
Main presentation

CTRISK by sector: real estate

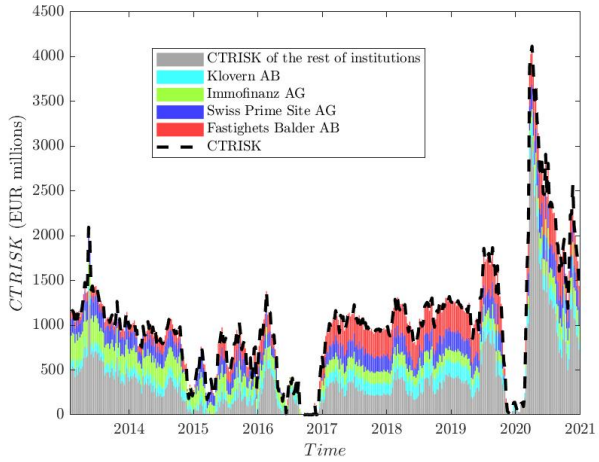
- Disorderly transition



- Orderly transition



- Hot house world



Main presentation

Appendix

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