Optimal climate policy in the face of tipping points and asset stranding

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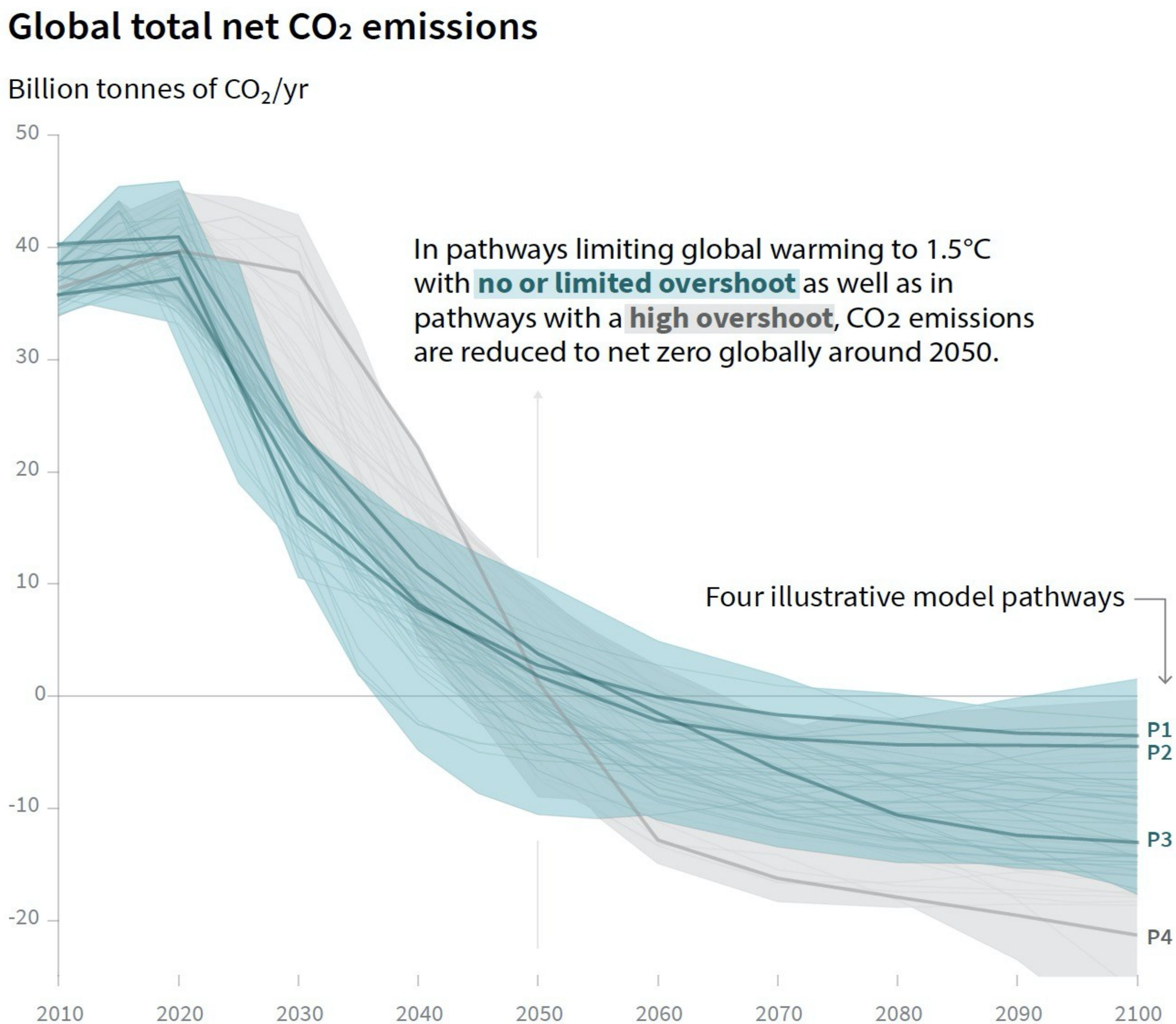
Aim of the paper

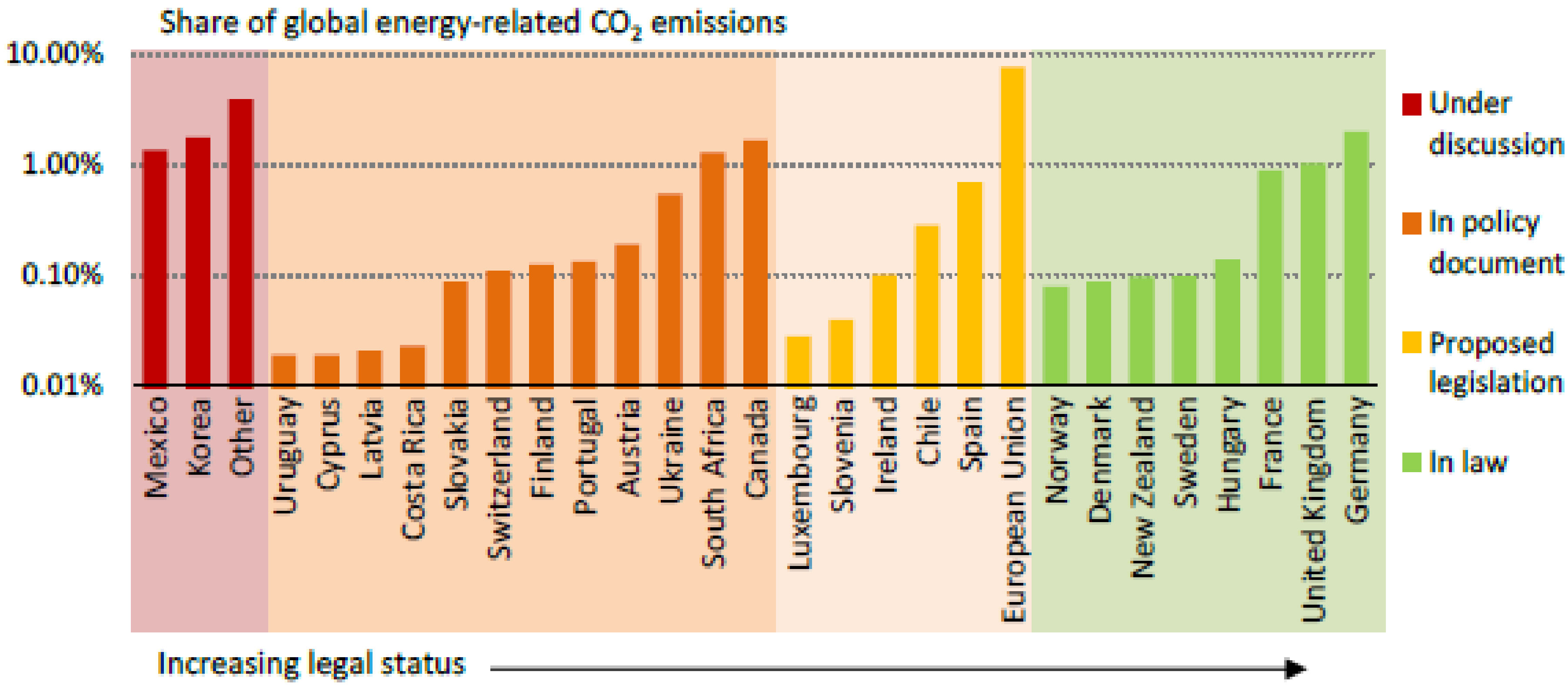
- Define optimal emissions path, optimal green investment and optimal dirty (dis)investment for the world economy
- Define optimal prudence in the face of
  - Macro economic risk
  - New information on the climate system
  - Possibility of a tipping point in the climate system
- What if we delay optimal policy?
- What if we want to keep dirty capital until their end-of-life?

Climate and mitigation objectives



Source: IPCC (2018)

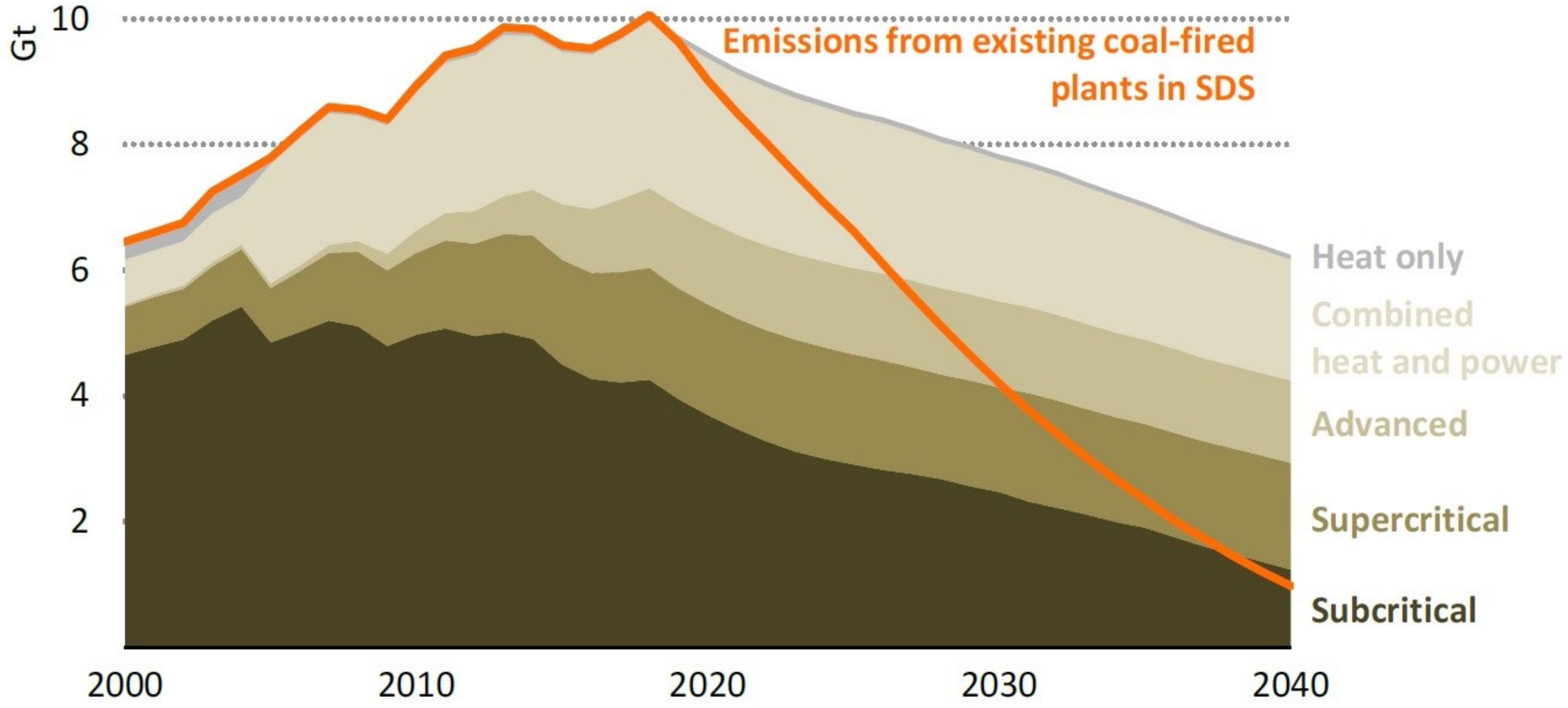
Figure 4.20 ▷ Announced net-zero CO_2 or GHG emissions by 2050 reduction targets



More than a dozen countries and the European Union, which accounted for around 10% of global CO_2 emissions in 2019, have net-zero emissions targets in law or proposed legislation

IEA, world Energy Outlook 2020.

Figure 6.17 ▷ Global CO_2 emissions from existing coal-fired power plants by technology with a 50-year lifetime in the Stated Policies Scenario

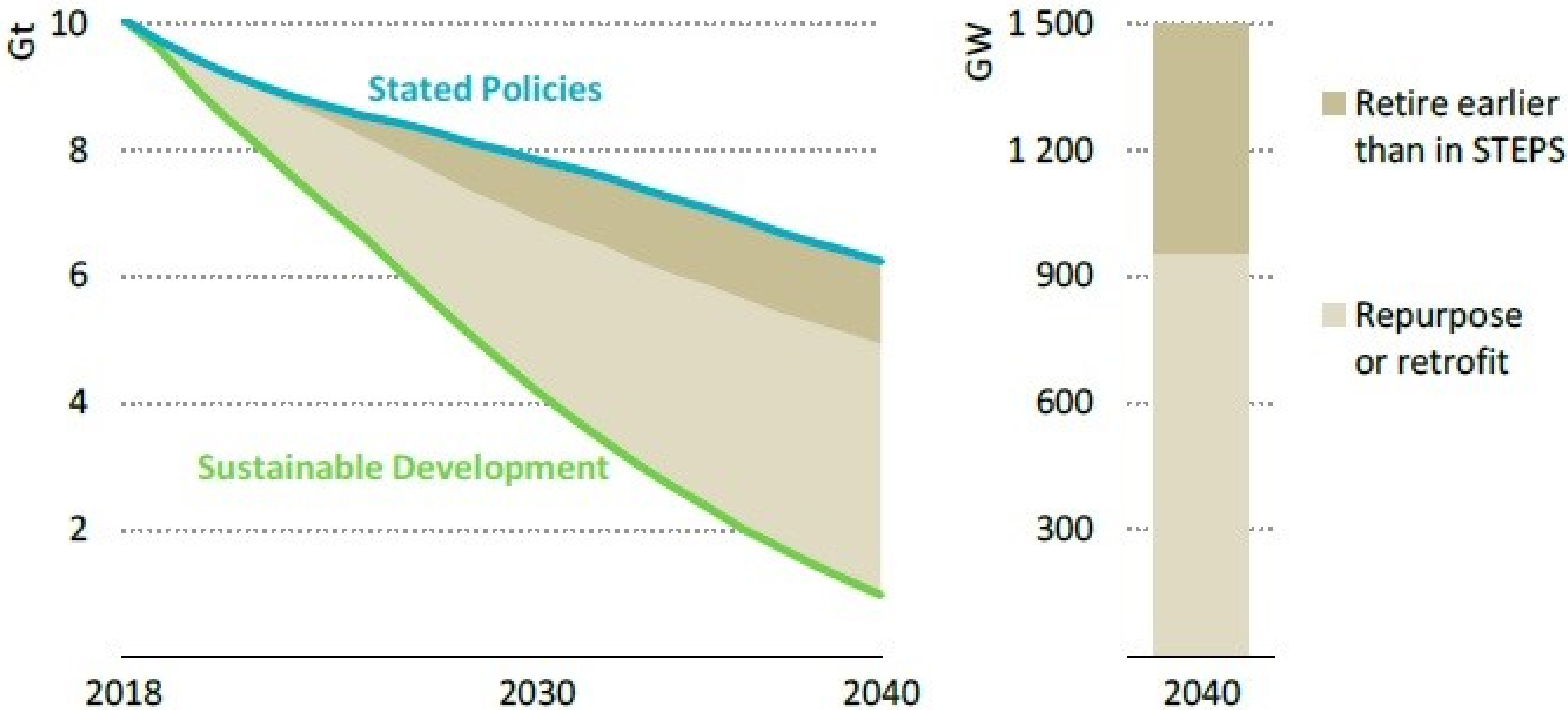


With a 50-year lifetime, existing coal-fired power plants would produce 175 Gt CO_2 in the period to 2040

Note: SDS = Sustainable Development Scenario.

IEA, world Energy Outlook 2020

Figure 6.20 ▹ Reducing CO_2 emissions from existing coal-fired power capacity by measure



Curbing CO_2 emissions from coal-fired power plants can be done cost effectively by retrofitting, repurposing and retiring the existing fleet

IEA, world Energy Outlook 2019

Locked into high-carbon capital assets

- Many of existing physical capital stocks are fossil-based
  - Coal/gas power plants and distribution networks
  - Steel mills
  - Road networks
- Physical capital stocks
  - Long-lived (e.g. 50 years for coal plants)
  - Large initial investments under expectation of productive asset life
  - Costly to repurpose to other (low-carbon) uses

In between 2 extreme strategies

No stranding strategy ⟺ **Abrupt stranding strategy**

This minimises stranding costs and contributes to smoothing the transition…

…but it warms the earth fast and accentuates tipping point risks

Scrap today high-carbon capital stocks ahead of their natural end-of-life…

…but, if done abruptly, it would create large stranding costs

Integrated assessment model

- Economic growth model + climate
- We maximize welfare
  - Different from minimizing costs for a given temperature target.
- A top down/general equilibrium model
  - Focus on dynamic optimization and risk assessment
  - Different from engineering/energy models with a lot of detail

Social Cost of Carbon = Marginal Abatement Cost

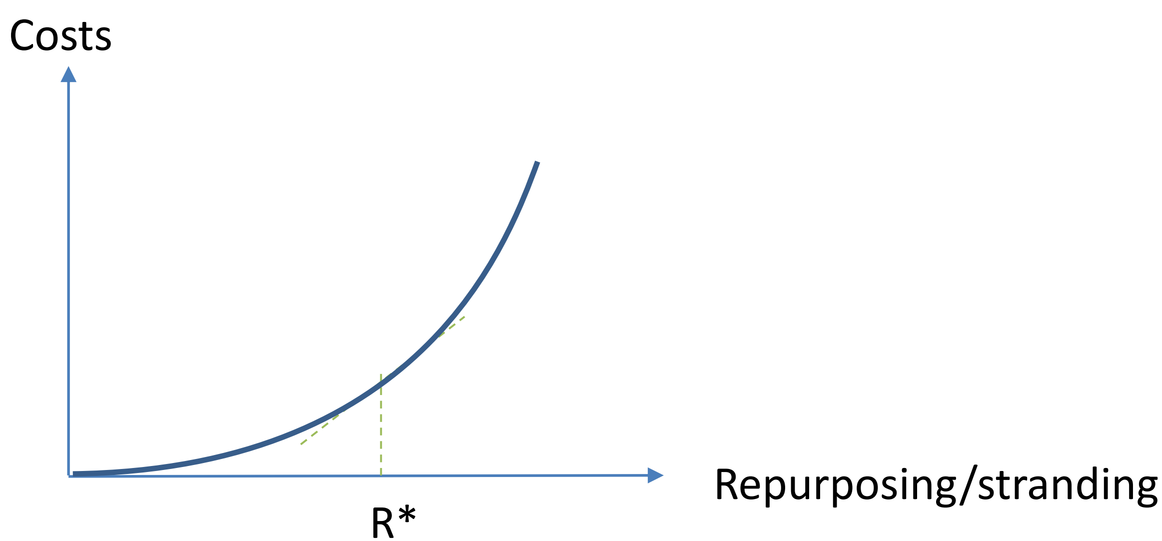
- Reducing one unit of emissions avoids a continued stream of climate damages in the future (SCC)
- Reducing an extra unit of emissions is costly (MAC)
  - Low emission technologies are more expensive than high-emission technologies.
  - Low emission technologies are even more expensive if
    - they replace high-emission technologies before end-of-life,
    - they are retrofitted to existing capital
    - lead to macro-economic adjustment costs

Our contribution

- The model has three distinctive characteristics:
  - Rigidities associated with both capital accumulation and capital conversion (stranding)
  - Data-driven emission abatement cost function
  - Multiple climate and economic uncertainties captured by stochastic processes

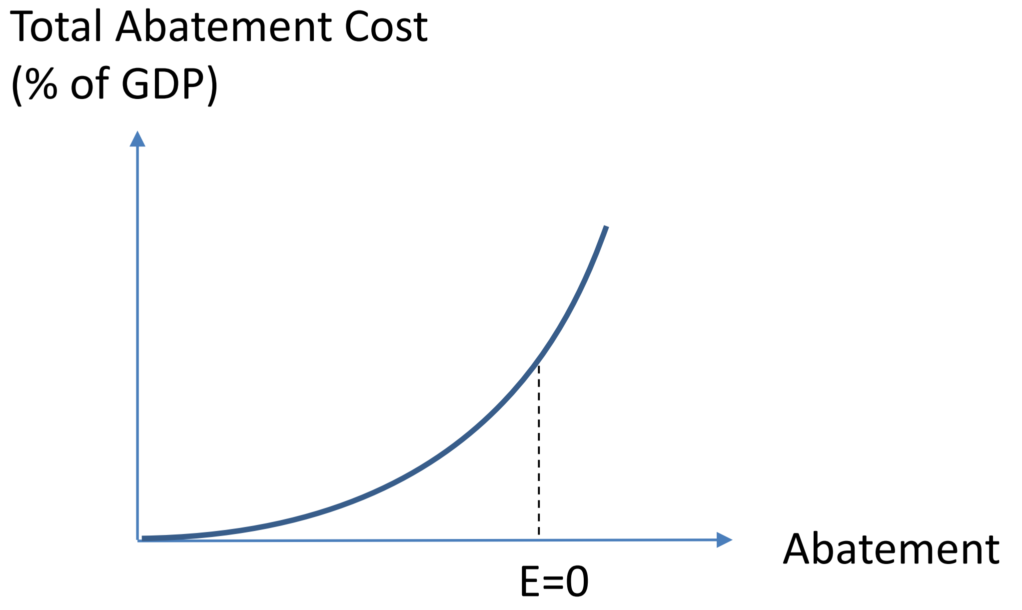
1 Stranding/repurposing costs

- Emissions decreasing at more than 5,5% per year requires repurposing/stranding
  - Decay rate of dirty capital 4%
  - Decrease of carbon intensity of dirty capital 1,5%
- Repurposing is cheap for small amounts and costly for large amounts.



2. Costs of emission reductions

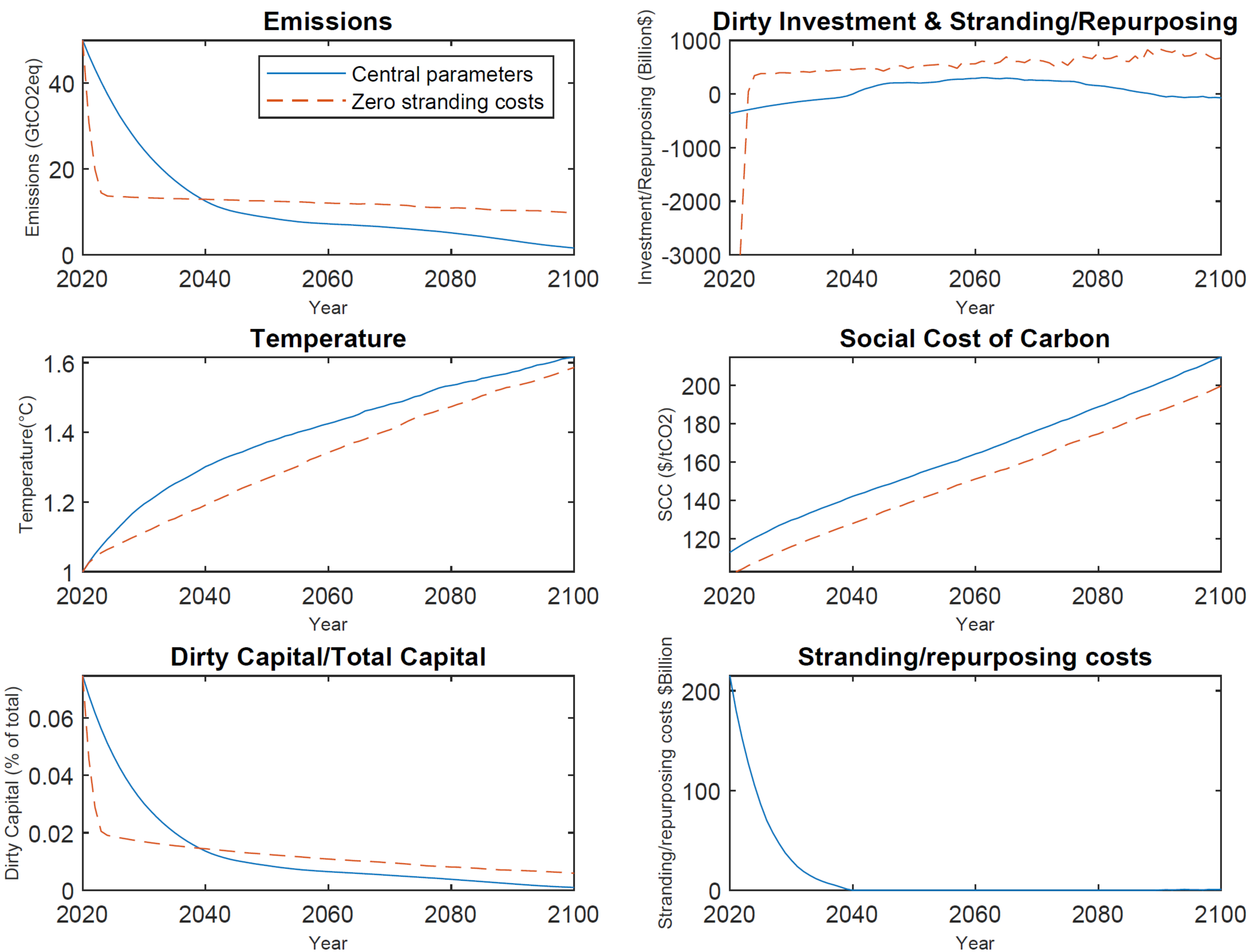
- Costs of emission reductions in our model are fitted on data from detailed energy system models contained in the IPCC database.

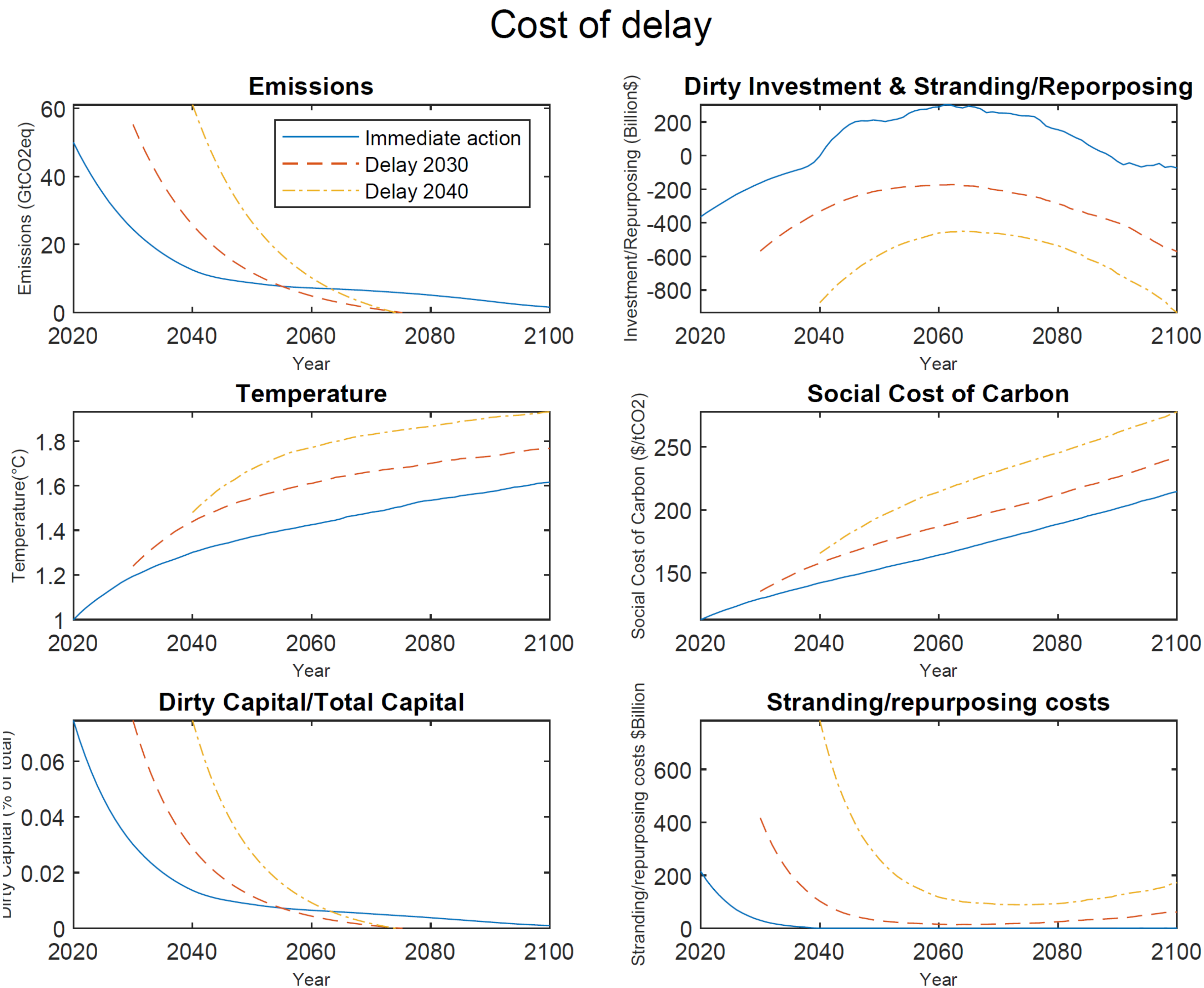


3. Uncertainty

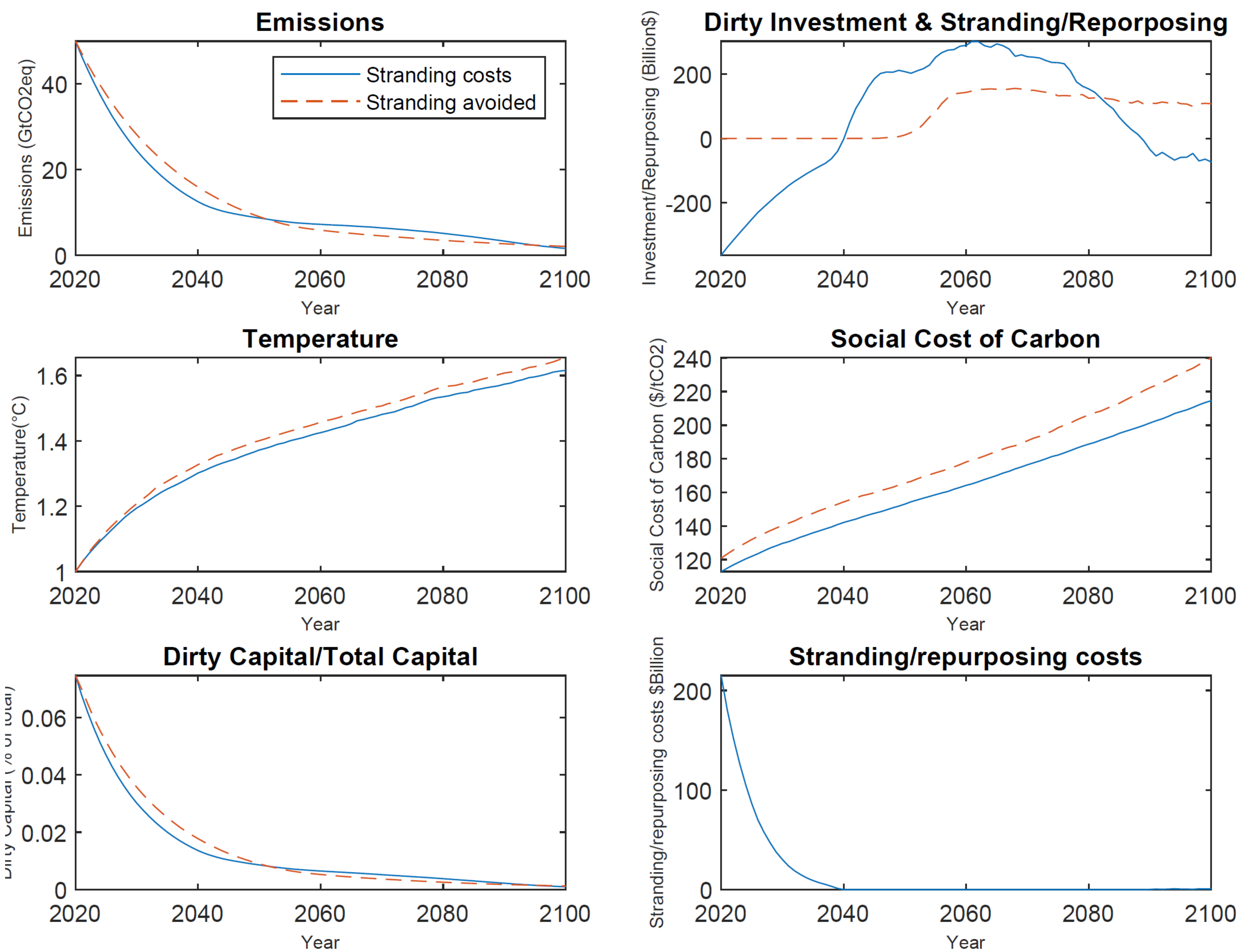
- Economic uncertainty
  – Correlated Brownian motions on both types of capital stocks
- Climate uncertainty
  – Brownian motion on temperature
  – Jump on temperature
- We employ Epstein-Zin-Weil preferences
- Dynamic programming: optimal prudence today, knowing that we can adapt optimally to new information in the future

Central parameters vs absence of inertia




Cost of delay
Emissions
Emissions (GtCO2eq)
Immediate action
Delay 2030
Delay 2040
Year
Dirty Investment & Stranding/Reporposing
Investment/Repurposing (Billion$)
Temperature
Temperature(°C)
Social Cost of Carbon
Social Cost of Carbon ($/tCO2)
Dirty Capital/Total Capital
Dirty Capital (% of total)
Stranding/repurposing costs
Stranding/repurposing costs $Billion

Should we avoid stranding?



Conclusions

- Inertia of dirty capital has a large impact on the optimal emission scenario. The social cost of carbon is 15% higher.
- Starting in 2020
  - repurpose/strand 350 $Billion of dirty assets per year (1.5% of total investment)
  - at a cost of 190 $Billion per year.
- Delay until 2030
  - stranded assets are 80% larger
  - repurposing/stranding costs double.
- Policies that try to avoid repurposing/stranding
  - social cost of carbon which is 10% higher
  - A net welfare loss of 10 $Trillion.
- I countries believe the Paris agreement with be respected; they can avoid stranded assets by stringent climate policy today.

Back-up slides

Equations

Emissions

$$E = \psi_t K_d$$

Production

$$Y = A_t L_t^{1-\alpha}(K_c + K_d\ )^{\alpha}\ e^{\phi_t E - \varphi_t E^2 + \beta \dot{E} - \gamma T^2}$$

Capital dynamics with financial adjustment costs and geometric Brownian motion

$$dK_c\ = (I_c - \zeta I_c^2 - r - \delta K_c)dt + \sigma_c K_c dW_c$$

$$dK_d\ = \left(I_d - \zeta I_d^2 + r - \theta_1 r^{\theta_2} - \delta K_d\right)dt + \sigma_d K_d dW_d$$

Consumption is production net of investments

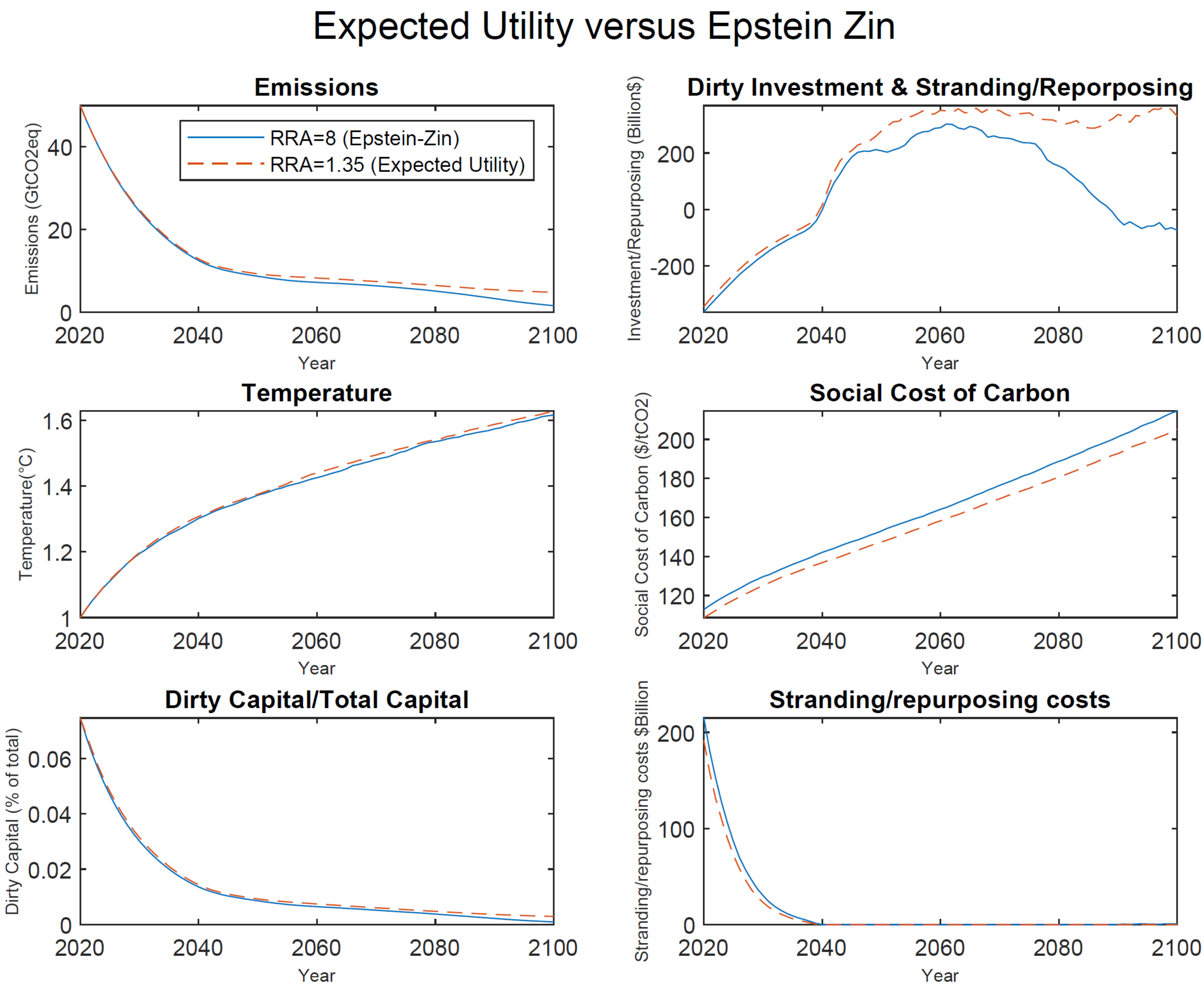
$$C = Y_f - I_c - I_d$$

Temperature follows a Brownian motion and jump process

$$dT = \hat{\xi} Emissions\ dt + \sigma_T dW_T + \lambda_T dP$$

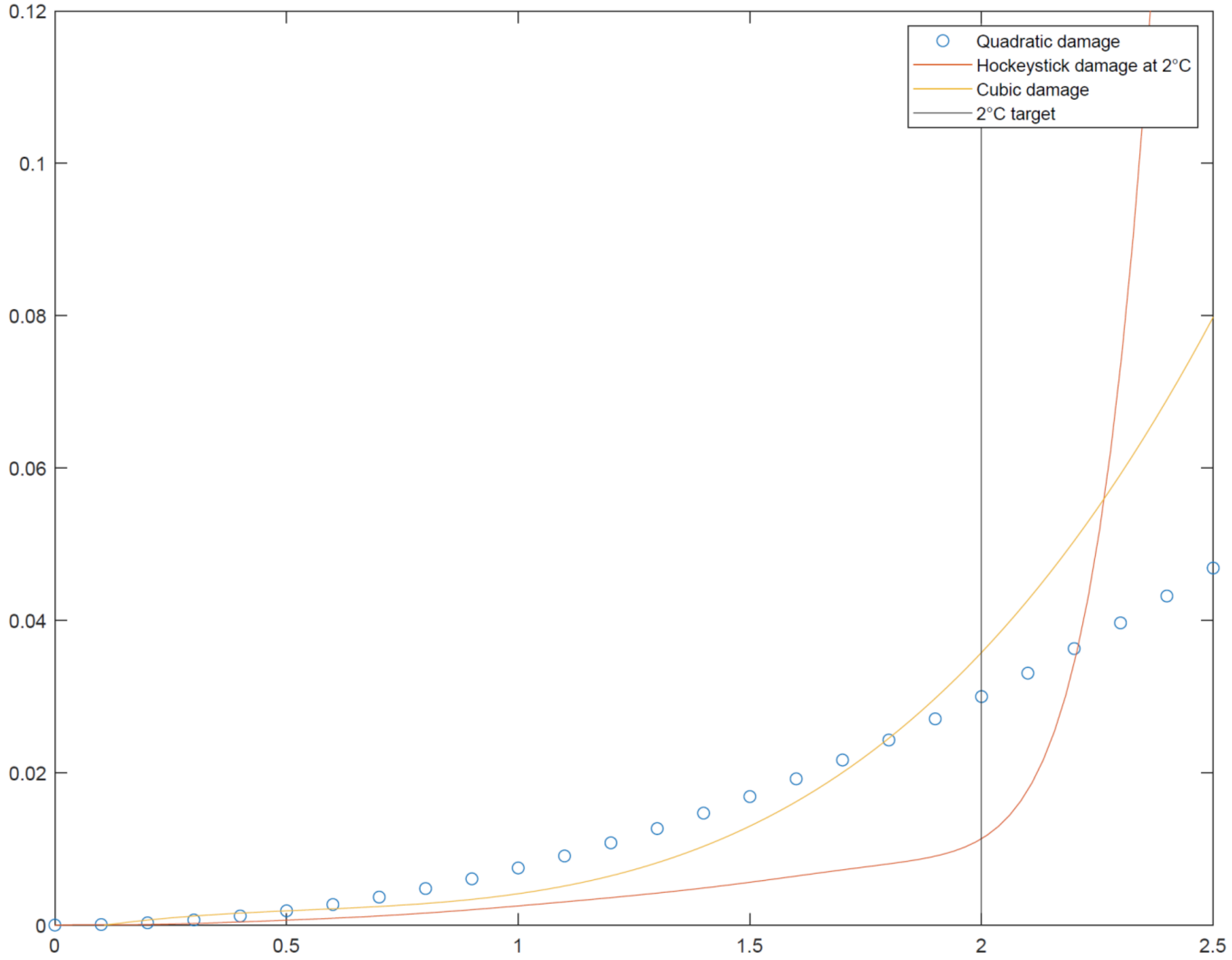
Optimization for expected utility (main model uses Epstein-Zin)

$$\max_{I_d, I_c} \int_0^{\infty} e^{(\rho - n)t} u\left(\frac{C}{L}\right) dt$$

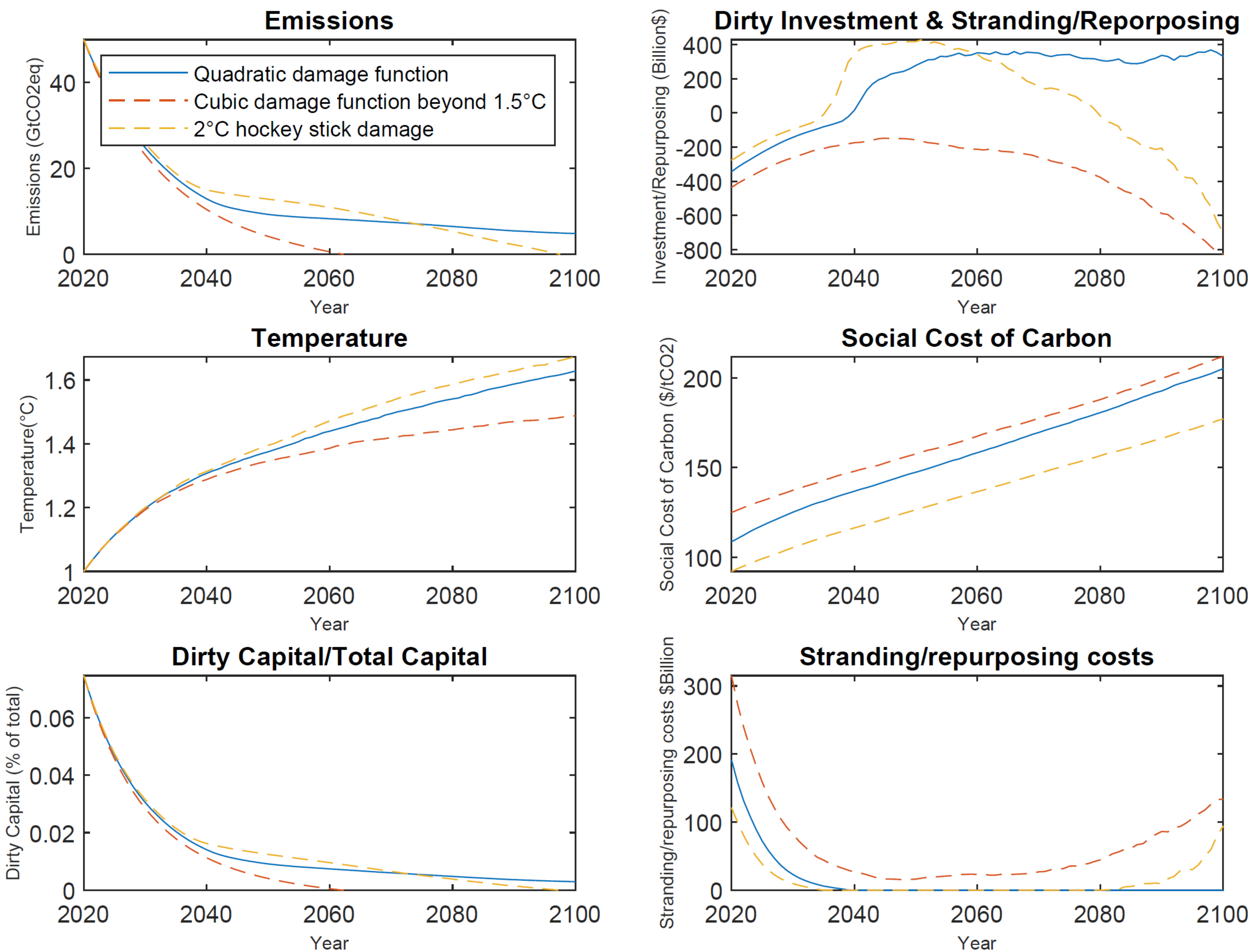


Expected Utility versus Epstein Zin
Emissions
Emissions (GtCO2eq)
RRA=8 (Epstein-Zin)
RRA=1.35 (Expected Utility)
Year
Dirty Investment & Stranding/Reporposing
Investment/Repurposing (Billion$)
Temperature
Temperature(°C)
Social Cost of Carbon
Social Cost of Carbon ($/tCO2)
Dirty Capital/Total Capital
Dirty Capital (% of total)
Stranding/repurposing costs
Stranding/repurposing costs $Billion

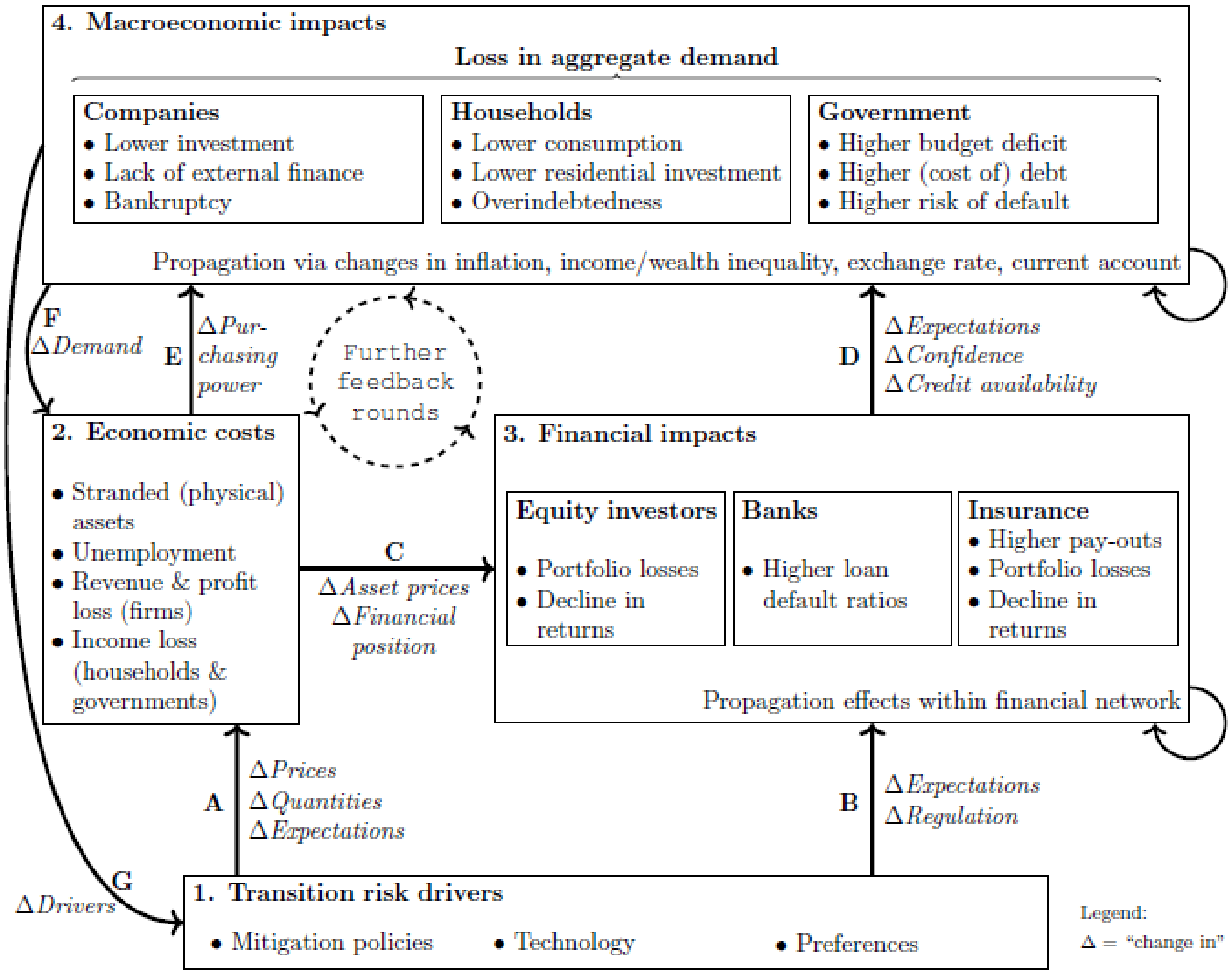
Damage as % of GDP vs warming



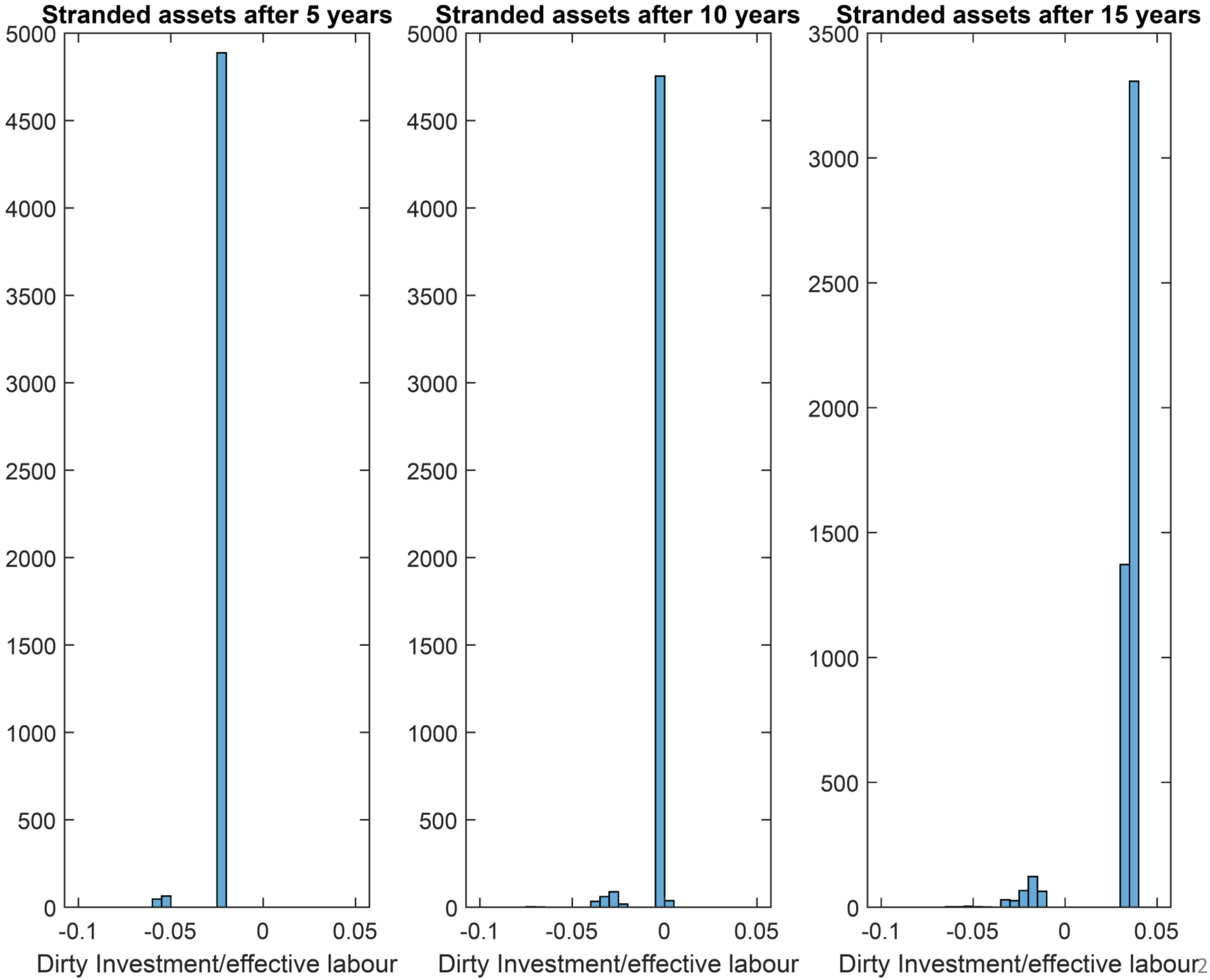
2°C hockey stick damage vs quadratic damage

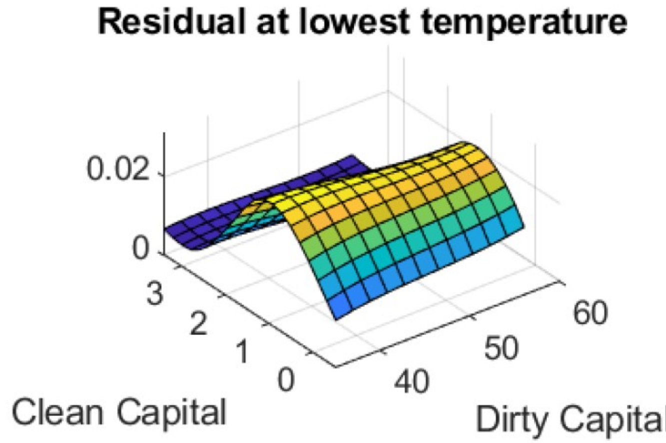


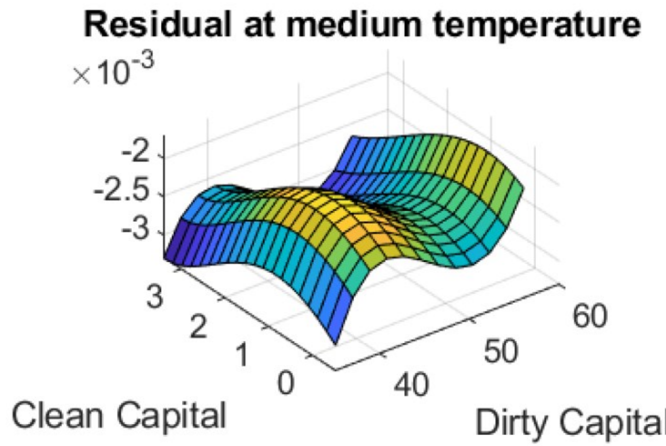
Macro-financial transition costs

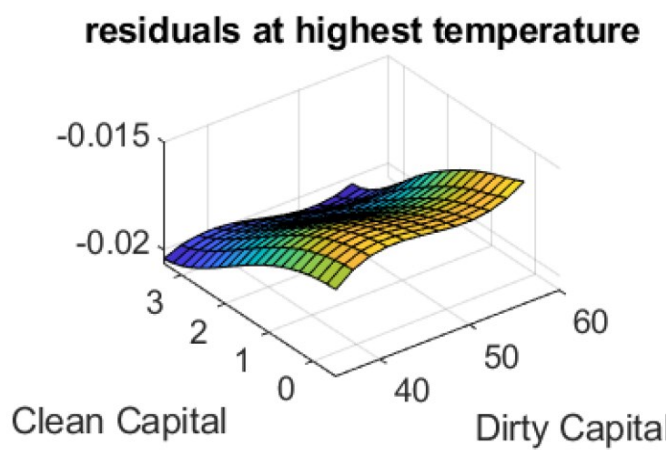


Source: Semieniuk et al. (2020)


Stranded assets after 5 years
Stranded assets after 10 years
Stranded assets after 15 years
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-0.1
-0.05
0
0.05
Dirty Investment/effective labour


Residual at lowest temperature
0.02
0
3
2
1
0
Clean Capital
40
50
60
Dirty Capital


Residual at medium temperature
×10^-3
-2
-2.5
-3
3
2
1
0
Clean Capital
40
50
60
Dirty Capital


residuals at highest temperature
-0.015
-0.02
3
2
1
0
Clean Capital
40
50
60
Dirty Capital

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