Discussion of:

“Optimal Climate Policy in the face of Tipping Points and Asset Stranding” by Campiglio, Dietz and Venmans

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MOST IAM'S HAVE ONLY ONE SECTOR

- Quantitative IAMs: DICE-2016 by William Nordhaus, FUND by Anthoff and Tol, PAGE by Hope, etc. Used a lot for policy analysis
- Other numerical energy models are used to assess costs of meeting pre-defined emission targets
- Analytical IAMs: Golosov et al. (2014), Gerlagh and Liski (2018), Lemoine and Rudik (2017); huge number of applications of Brock-Mirman structure of Golosov et al.
- Most of these models have too much temperature inertia but not Golosov et al. – see earlier seminar by Simon Dietz
- They have no stochastics and, if they do, they wrongly use Monte Carlo
- Golosov et al. (2014) has EIS=RRA=1 so all effects of uncertainty drop out
- But many now allow for stochastics including tipping points using stochastic versions of DICE: Gollier; Crost and Traeger; Jensen and Traeger; Lemoine and Traeger; Cai and Lontzek (2019); etc. Others appeal to asset pricing: Daniel et al. (2019)
- Van den Bremer and van der Ploeg (2019) and Traeger (2019) given analytical solutions for carbon pricing in risky environments, and Hambel et al. (2020) do this for a 2-sector model

THE OPTIMAL CARBON PRICE AND RISK-ADJUSTED DISCOUNTED RATE BOIL DOWN TO:

$$P = \frac{\mu\,\Theta Y}{r^{\text{å}}}\left(1 + \Delta_{\chi} + \Delta_{\lambda} + \Delta_{CK} + \Delta_{CC}\right)$$

with

$$r^{\text{å}} = \rho + (IIA - 1)\left(g^{(0)} - \frac{1}{2} RRA\ \sigma_K^2\right) + \varphi$$

for case of proportional reduced-form damages and ignoring carbon stock uncertainty

DRIVERS OF RISK-ADJUSTED DISCOUNT RATE

$$(4.2)\quad r^{\star} = \underbrace{\rho}_{\text{time impatience}} + \underbrace{\gamma g^{(0)}}_{\text{rising affluence}} - \underbrace{g^{(0)}}_{\text{growing damages}} \underbrace{-\frac{1}{2}(1+\gamma)\eta\sigma_K^2}_{\text{prudence}} + \underbrace{\eta\sigma_K^2}_{\text{insurance}} + \underbrace{\varphi}_{\text{decay atmospheric carbon}} .$$

- Here ρ = utility discount rate, γ is IIA = 1/EIS, and η = RRA
- If IIA = γ = 1, the prudence and insurance effects offset each other so that the discount rate boils down to $\rho + \varphi$
- Economic uncertainty has zero effect on the carbon price

DANIEL, LITTERMAN AND WAGNER (2019, PNAS)

- Uses binomial tree (7 periods) asset pricing model to show that optimal carbon price declines over time
- This requires (i) preference for early resolution of uncertainty (Epstein-Zin with RRA > 1/ EIS) and (ii) gradual resolution of damage ratio uncertainty
- Olijslagers et al. (2020): revisits with continuous-time model and shows that optimal carbon price consists of a *rising* component proportional to GDP and a *declining* component that depends on uncertainty considerations; usually, the first component swamps the second component
- Van der Ploeg and de Zeeuw (2018): show that in a tipping model with a *one-off* temperature-dependent risk of a big increase in damages, the carbon price declines after the tip
- Hambel et al. (2020) look at *recurring* Barro-style disasters, where incidence of the climate-related disasters increases with temperature, not *one-off, irreversible* disasters

MESSAGES FROM CAMPIGLIO, DIETZ AND VENMANS

- What if we delay optimal climate policy? Much more costly? Why?
- What if carbon-intensive capital gets stranded? Coal-fired power stations will need to be scrapped before end of economic lifetime (Caldecott et al.)? Steel and cement factories too? Economic lifetime can be more than 50 years and costly to repurpose/reallocate to low-carbon uses
- Replacing carbon-intensive technologies before end of life is very costly
- Avoid disorderly transition else abrupt stranding of assets at high costs
- Use one-sector DSGE model of macroeconomy and climate system with two capital stocks to evaluate costs of optimal and of delayed climate policy
- Not a temperature cap and Hotelling rule for the carbon price, but externalities from global warming and carbon price grows in line with world GDP

LOOKING UNDER THE BONNET OF CAMPIGLIO, DIETZ AND VENMANS

- Nice to have risk aversion > 1/elasticity of intertemporal substitution: preference for early resolution of uncertainty
- Some concerns:
  - Why only one sector with two types of capital instead of multiple green and dirty sectors?
  - Why are carbon-intensive capital and green capital perfect substitutes in production?
  - Why not homogenous investment adjustment and reallocation costs? In that case marginal Q would equal average Q
  - There are no tipping points: there are recurring Poisson-style disaster shocks a la Barro, no tipping points such as melting of Ice Sheets, reversal of Gulf Stream or melting of Permafrost familiar from climate science
  - Extra costs from global warming: Why? How to calibrate?
  - Costs of delay, but how about costs and macro and financial implications of the risk of policy tipping and risk of an abrupt breakthrough in renewable energy technology

- Why no disaster shocks in output (instead of temperature process) as in Barro and Jin? Why no climate-related disaster shocks as in Hambel et al. ?
- Damage/output increasing function of *emissions and speed of emission reductions* from 24 detailed energy models & 89 scenarios from IPCC (2014): why not use real data?
- Emissions falling by more than 5.5% per year require repurposing/stranding? Why? A way to capture non-zero stranding costs?
- They use a top-down general equilibrium model: corresponds to finding a command optimum and then showing it can be sustained in market economy
- That can be done if a carbon tax is introduced equal to the SCC and revenue is rebated in lump-sum manner (or a competitive permit market) for *first-best* optimal policy, but cannot be done for *delayed second-best* optimal policy
- Much harder problem: must maximise expected welfare subject to constraints of decentralised market economy.
- Fundamental theorem of welfare economics no longer holds and time inconsistency issues will undoubtedly occur with investments costly to adjust or repurpose

POLICY SIMULATION RESULTS

- With stranding costs less abrupt decline in emissions and share of dirty capital, and higher paths for SCC (15% higher) and temperature: optimal first-best policy internalises these costs and tries to avoid them
- With delayed second-best optimal carbon pricing, SCC paths and temperature paths will eventually be much higher while dirty share of capital and emissions take longer to fall and stranding/repurposing costs are much higher!
- Delay until 2030 imply stranded assets are 50% higher and stranding costs double
- No Green Paradox effects (oil etc not scarce so emissions not higher in short run); with those effects delayed policies are more costly
- Do more with early resolution of uncertainty?

RISK OF STRANDED ASSETS

- vd Ploeg and Rezai (2020ab): shows effects of the risk of policy tipping on market valuations of oil companies; policy uncertainty and costly adjustments of capital stocks leads to stranded assets
- vd Ploeg (2020): game-theoretic approach to "race to burn the last ton of carbon" and risk of stranded assets; mere risk of a cap on global warming at some unknown, future date makes oil extraction more voracious and accelerates global warming (cf. Green paradox)
- Barnett (2020): an uncertain arrival time of policy change generates a run on oil, so falls in spot price of oil and market valuation of companies, increase in green energy price and higher temperature; considers SDF and asset pricing implications; potential carbon bubble

MIXED EMPIRICAL EVIDENCE

- Bolton and Kacperzyk (2020a): carbon-intensive firms (steel, cement, oil majors, etc.) in US show higher stock market returns after controlling for size, book to market, momentum, etc. as investors already demand compensation for the carbon risk; this carbon risk premium cannot be explained via unexpected profitability or other risk premia
- Bolton and Kacperzyk (2020a): similar exercise for cross section of 14,400 firms in 77 countries shows evidence of *rising* carbon risk premia for carbon-intensive stocks
- Institutional investors are divesting away from carbon-intensive firms

But:

- In, Park and Mong (2019, Stanford): looking at 736 US firms from 2005-2015, EMI (carbon-efficient minus carbon-inefficient) portfolio has from 2010 onwards positive abnormal returns; investment strategy of going long on carbon-efficient firms and going short on carbon-inefficient firms would earn abnormal returns of 3.5%-5.4% per year (not driven by low *r*'s after GFC); carbon-efficient firms are "good" in terms of financial characteristics and governance

MIXED EMPIRICAL EVIDENCE CTD.

- Garvey, Iyer and Nash (2018): firms that have a lower ratio of carbon emissions to sales (the "E in ESG") and are less dependent on carbon have stronger future profitability and higher stock returns

- Plantinga and Scholtens (2020): looking at 7,000 companies over 40 years, they find that investment portfolios that exclude fossil fuel production companies do not perform worse than unrestricted portfolios, so they suggest that divesting from fossil fuel companies does not hurt stock market performance

DONADELLI, GRÜNING AND HITZEMANN (2020, CEBRA)

- Focuses at the fossil fuel industry to circumvent classification issues
- Price-dividend ratio high but fell since 2008 at time of bust of commodity price boom
- Better econometrics to explain changes in value along trends in climate change awareness:
  - Explains market to book ratio of about 4,000 firms over 1970-2018
  - Uses panel regression to control for market-wide valuation and other trends
  - Depends on awareness of climate change risks (from Google searches, closely correlated with environmental policy stringency)
  - Controls for cash/assets, debt/assets, log assets, R&D/sales
- Empirical findings:
  - Stock market value of US oil and fossil fuel firms has fallen a lot over last 20 years compared to other firms
  - Markets have started to price in the climate transition (negative coefficient on climate awareness index)

POSSIBLE IMPROVEMENTS

- Investors may have non-pecuniary preferences for green companies and accept a lower Sharpe/reward to variability ratio to speed up greening of economy; is it ethical to keep dirty assets as a hedge?
- **Environmental impact investing**: have a general equilibrium model with a continuum of firms where each of their carbon footprints is made endogenous and where the effect of this via the carbon tax on their capital cost makes them reduce their footprint (cf. Oehmke and Opp, 2020; Landier and Lovo, 2020; Pastor et al., 2020, JFE; De Angelis et al., 2020)
- E.g. if fraction of assets managed by green investors doubles, carbon intensity of companies in portfolio drops by 5% per year (De Angelis et al., 2020)
- Depart from global economy by studying either a small open economy with an agreed carbon budget or a game between countries

GREEN TRANSITION RISK

- Carbon-intensive firms may face risk of default if there is a sudden future stepping up of climate policy (cf. Barnett, 2019) or breakthrough in green technology
- Extend a model with limited liability, average risk pricing of deposits and excessive leverage, and thus need for *differential* capital requirements (Mendecino et al., 2020, JME)
- Does this require differential prudential policies for green and dirty assets?
- Carbon risk premium found by B&K seems related to transition policy risk (Hsu et al., 2020) and this transition risk differential is also observed in option markets (Ihan et al., 2020)
- After Paris agreements firms affected by transition risks have been charged higher interest rates (Delis et al., 2020)

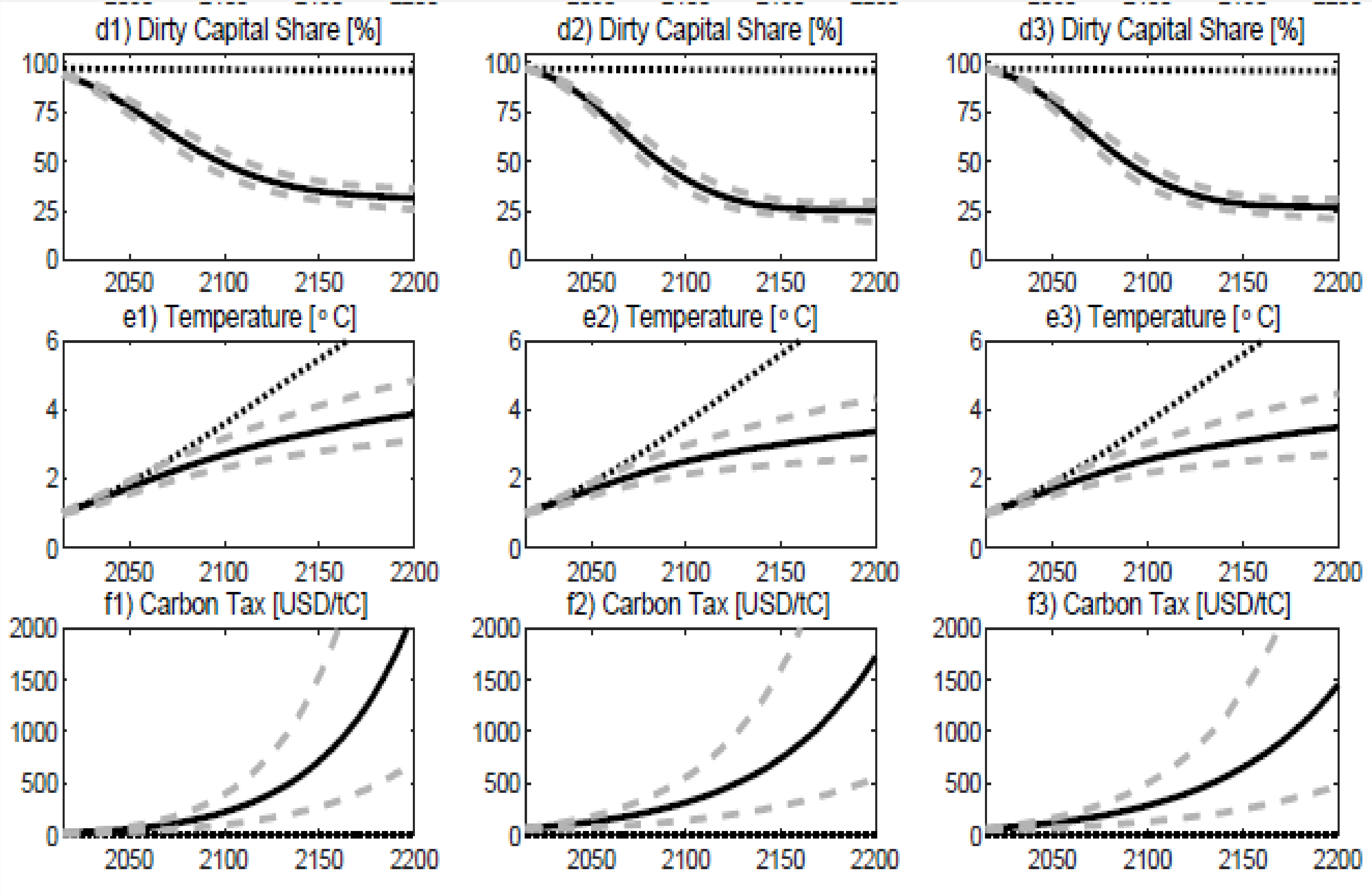
HAMBEL, KRAFT, VAN DER PLOEG

- Diversification perspective: diversify until there is a balance between green and dirty capital (cf. Cochrane et al., 2007)
- Environmental perspective: run down dirty capital stock completely
- The latter does not occur with DICE damages, but does occur if damages from climate change are much more severe or different damages are taken together
- Diversification considerations may prevent driving the dirty capital stock to zero
- We analyse dynamics of risk-free rate and risk premia during green transition:
  - The risk-free rate falls with rising temperature
  - Risk premia only significantly affected if risk of disasters increases with temperature (else impact on risk premia is moderate)

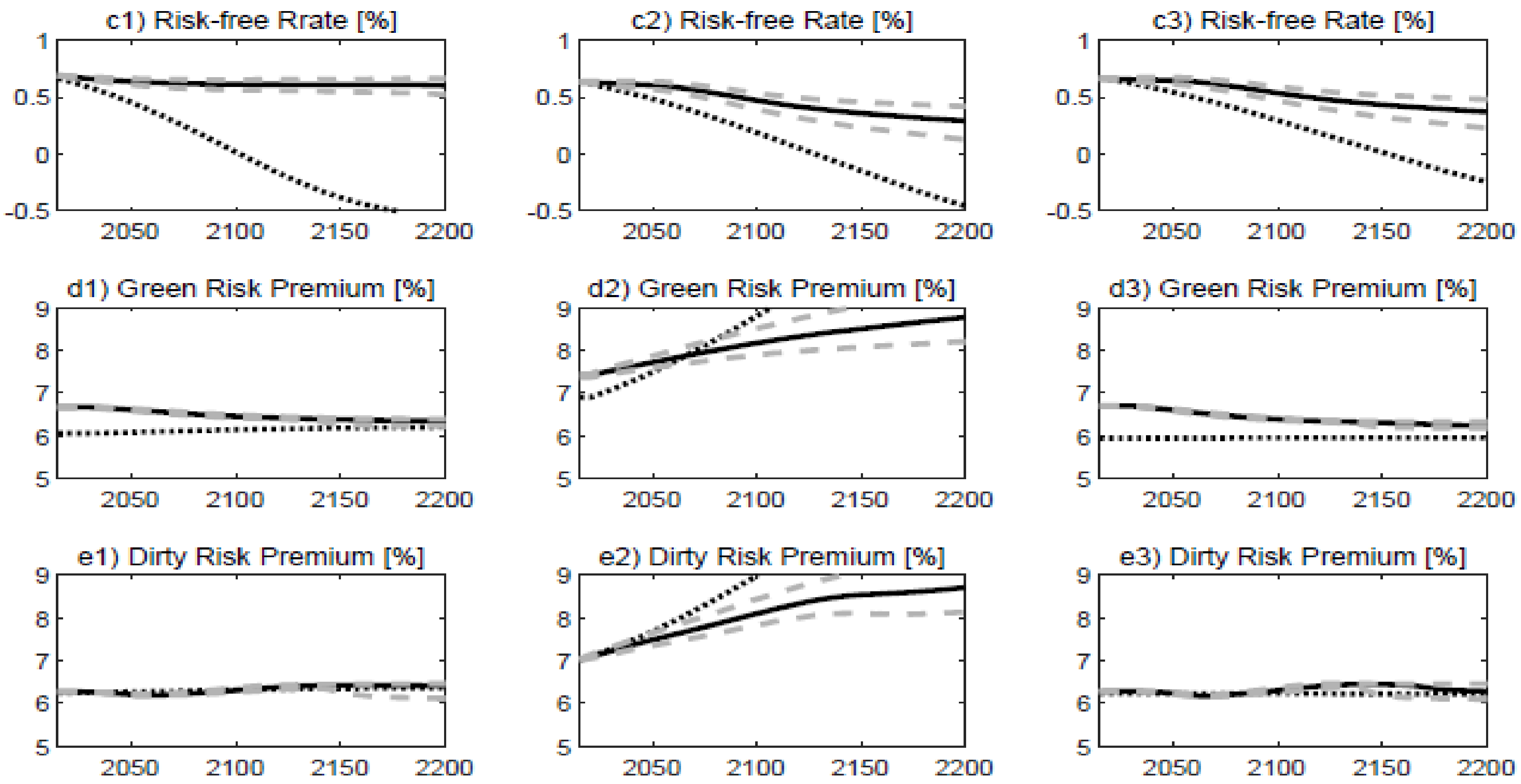
TIMES SERIES SOLUTIONS

- **Left column**: only temperature effect on TFP for aggregate production (Nordhaus)
- **Middle column**: only temperature effect on jump intensity of disasters (Karydas and Xepapadeas)
- **Right column**: only temperature effect on depreciation rate of capital

- Solid lines = optimal;
- Dashed lines = 5% and 95% confidence bounds for optimal
- Dotted lines = BAU


d1) Dirty Capital Share [%]
d2) Dirty Capital Share [%]
d3) Dirty Capital Share [%]
e1) Temperature [° C]
e2) Temperature [° C]
e3) Temperature [° C]
f1) Carbon Tax [USD/tC]
f2) Carbon Tax [USD/tC]
f3) Carbon Tax [USD/tC]
0
25
50
75
100
2
4
6
500
1000
1500
2000
2050
2100
2150
2200

Evolution of Asset Pricing Quantities



The figure depicts the simulation of asset pricing quantities for the three damage specifications level impact (1^{st} column), disaster impact (2^{nd} column) and growth rate impact (3^{rd} column) until the year 2200. The black dotted lines show the results for the BAU scenario.