MACRO-FINANCIAL IMPLICATIONS OF CLIMATE CHANGE AND THE CARBON TRANSITION

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2. NEED TO PRICE CARBON AND CHALLENGES

Pricing carbon via carbon tax or permit markets (ETS):

- curbs demand for fossil fuel
- encourages to leave more fossil fuel in crust of earth
- induces substitution from carbon-intensive (tar sands?, coal, crude oil) to less carbon-intensive fossil fuel (gas)
- induces substitution to renewables and brings forward carbon-free era
- boosts CCS and limits slash & burn of forests
- boosts R&D in clean fuel alternatives and energy-saving technology
- encourages households, firms and government to spend more on CO2 mitigation and CO2 adaptation (e.g. dykes)
- **Collateral benefits:** lower air pollution, better health

CHALLENGES IN PRICING CARBON

- **No brainers first:** moratorium on coal; get rid of coal and other fossil subsidies (6.5% of world GDP); no exemption for airlines
- **Climate risks are very far in the future:**
  - need a climate hedge which gives positive returns in future when global warming turns out to be much hotter than expected (dikes?)
  - Current generations must make sacrifices to curb future global warming to benefit of future, possibly richer generations, so need debt and transfers to get intergenerational win-win (Kotlikoff)
- **Need transfers from rich to poor countries:** to get uniform price throughout the globe but this has not happened …
- **Climate policy hurts the poor:** need to recycle regressive carbon tax or permit revenue to compensate lower income group but ..

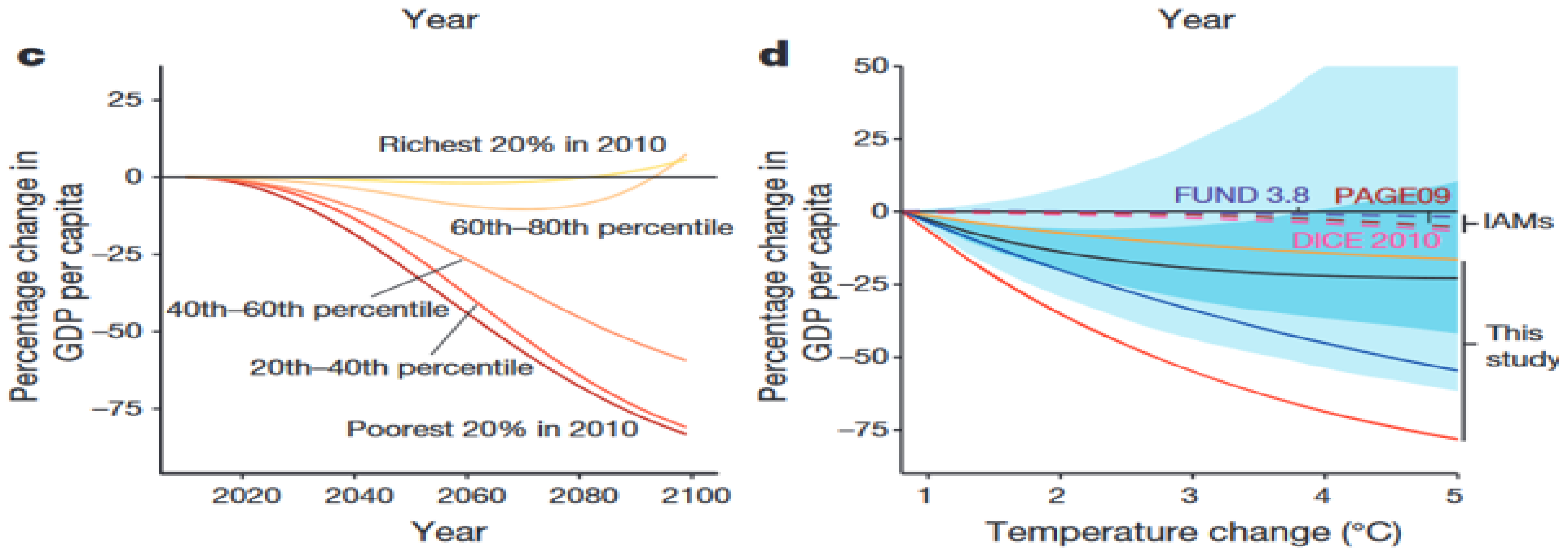
- **International free riding:**
  - carbon leakage if only some countries price carbon
  - need border tax adjustments to get level playing field
  - else production subsidies for steel, cement and other industries that are most at risk of foreign carbon-intensive competition
  - or climate tariff clubs (Nordhaus) or buy up forests (Coase)
- **Green Paradox:** politicians prefer to postpone and use the carrot instead of the stick $\rightarrow$ oil sheiks pump oil faster to avoid capital losses which accelerates global warming (especially if supply does not respond much to prices)
- **Policy failure and capture:** non-price controls, grandfathering, government picks winners, lobbies

3. CLIMATE POLICY: PIGOU VERSUS IPCC

- **Credibly commit to a rising path of carbon prices**
- **Pigouvian approach** sets carbon price to social cost of carbon or SCC, i.e. expected present value of all present and future marginal damages from emitting one extra ton of carbon today
- Key issue: what risk-adjusted discount rate to use?
- Must take account of economic and climatic uncertainties, “tail” risk and tipping points
- **IPCC approach** puts a cap on temperature and acts as focal point
- Cumulative emissions drive temperature, so corresponds to a cap on cumulative emissions or safe carbon budget
- The latter also depends on economic and climatic uncertainties

PIGOUVIAN APPROACH

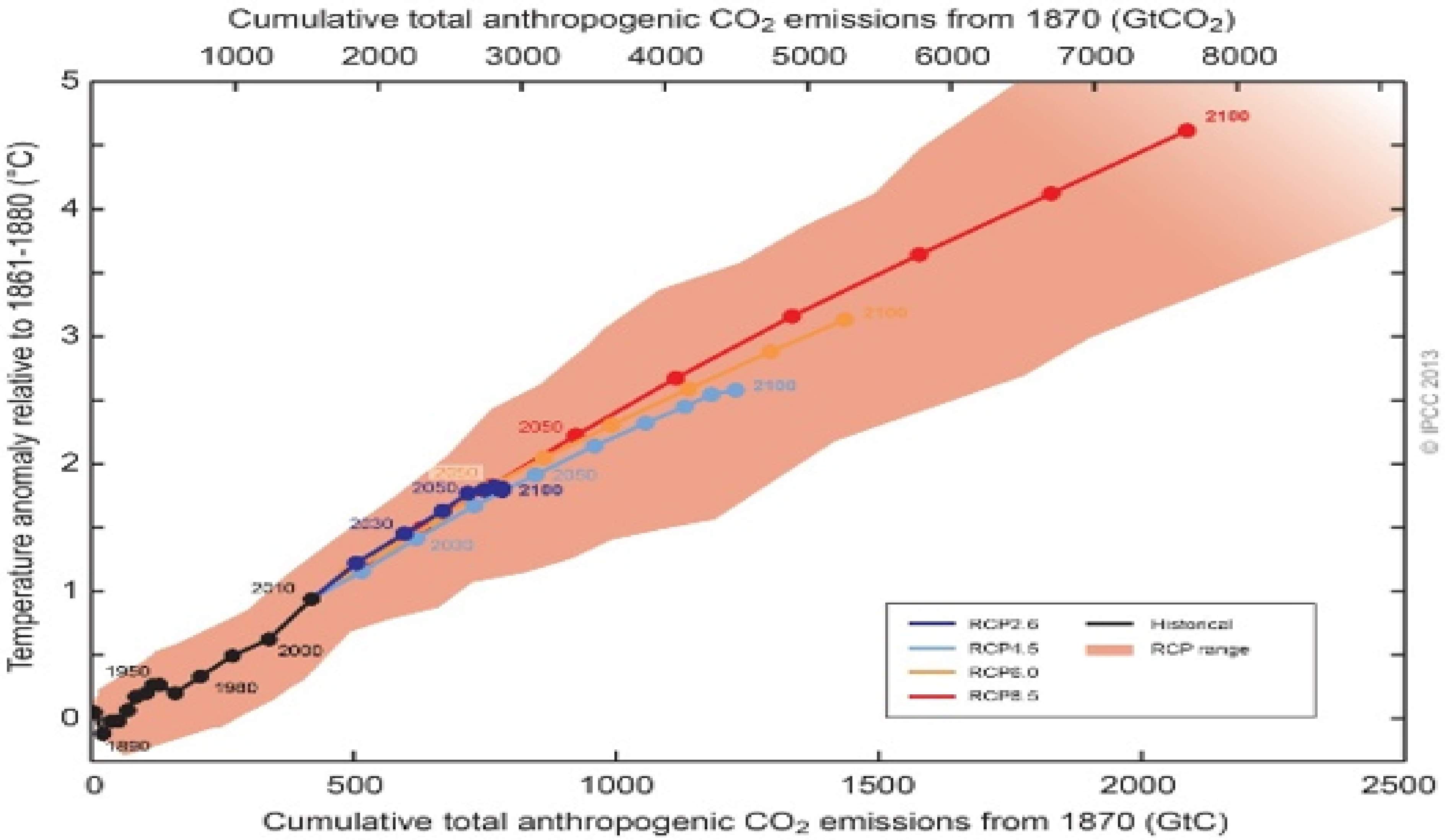
Figure 1: Damage ratios versus temperature



Key: Panel c gives the mean impacts by 2010 income quintiles for the benchmark model, which indicates that poorer countries suffer more from global warming than rich countries. Panel d plots the projected income loss in 2100 (SSP5) for different levels of global mean temperature increase relative to preindustrial temperatures. Blue shaded areas are interquartile range and 5th – 95th percentile estimates. Dashed lines show damages from the integrated assessment models DICE2010, FUND3.8 and PAGE09. Black indicates pooled response (short-run effect), orange the differentiated response (short-run effect), red the pooled response (long-run effect), and blue the differentiated response (long-run effect).

Source: Burke et al. (2015, panels c and d of Figure 5)

Figure 2: Cumulative carbon emissions drive temperature



- Here 12.5% of world GDP per degree Celsius is the output loss per degree Celsius from **Burke et al.** (2015, Nature)
- 1.8 degrees Celsius per trillion ton of cumulative emissions is the temperature response to cumulative emissions
- World GDP is roughly 80 trillion US dollars and growth rate = g = 2%/year
- The **Pigouvian price of carbon**:

  SCC = 12.5% x 1.8 x 80/discount rate

  where discount rate = impatience rate + IIA x g – g

  – (*prudence term* + *insurance term* + *other risk corrections*)
- If zero impatience and IIA =2, then (growth-corrected) discount rate 2%
- → Carbon price = $18/discount rate = $900/tC or **$245/tCO2**

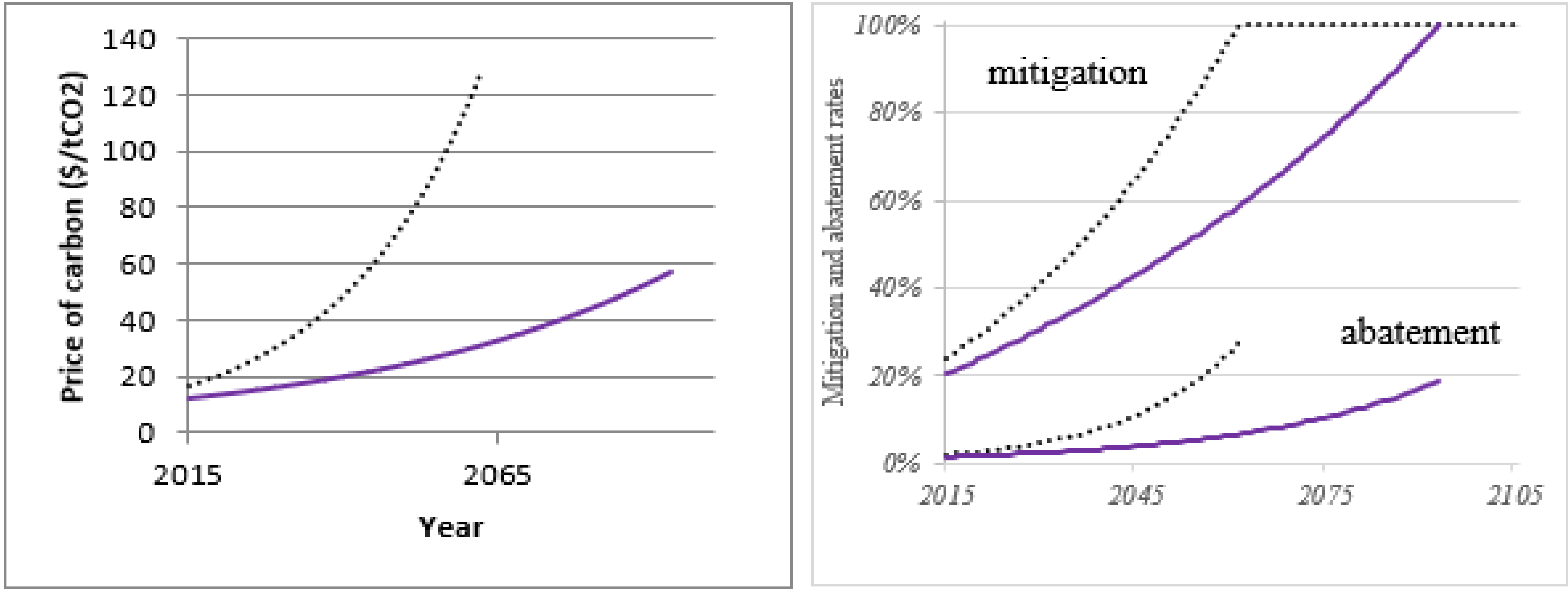
- If damages are 0.944% of world GDP at 2°C as in **Nordhaus** (2017), then SCC = $68/tC or **$18.5/tCO2**
- Lower growth (1%) pushes up SCC to $136/tC

TEMPERATURE CAP APPROACH

- Pigou gives wide range of estimates of SCC and tough to explain, so IPPC, NGFS and central banks adopt 2°C cap on temperature
- Corresponds to **cap on cumulative emissions**: 1TtC from 1870 or 550-1150 GtCO2 or 150-314 GtC from 2014 onwards
- At current global use of 10 GtC, carbon budget exhausted in 15-31 years
- Less with cap of 2°C or tighter risk tolerance
- Hence, keep fossil fuel reserves in the ground!
- To achieve this, the carbon price must grow at a rate equal to the risk-adjusted interest rate (Hotelling rule)

Solid lines: Pigouvian outcomes with Nordhaus damages
Dotted lines: outcomes under 2 degrees cap

Figure 3: Pigouvian versus carbon budget approaches to climate policy



Key: The mitigation rate is the share of renewables in total energy. The abatement rate is the fraction of emissions that is abated via CCS or other means. The solid lines correspond to the Pigouvian and the dotted line to the carbon budget approach.

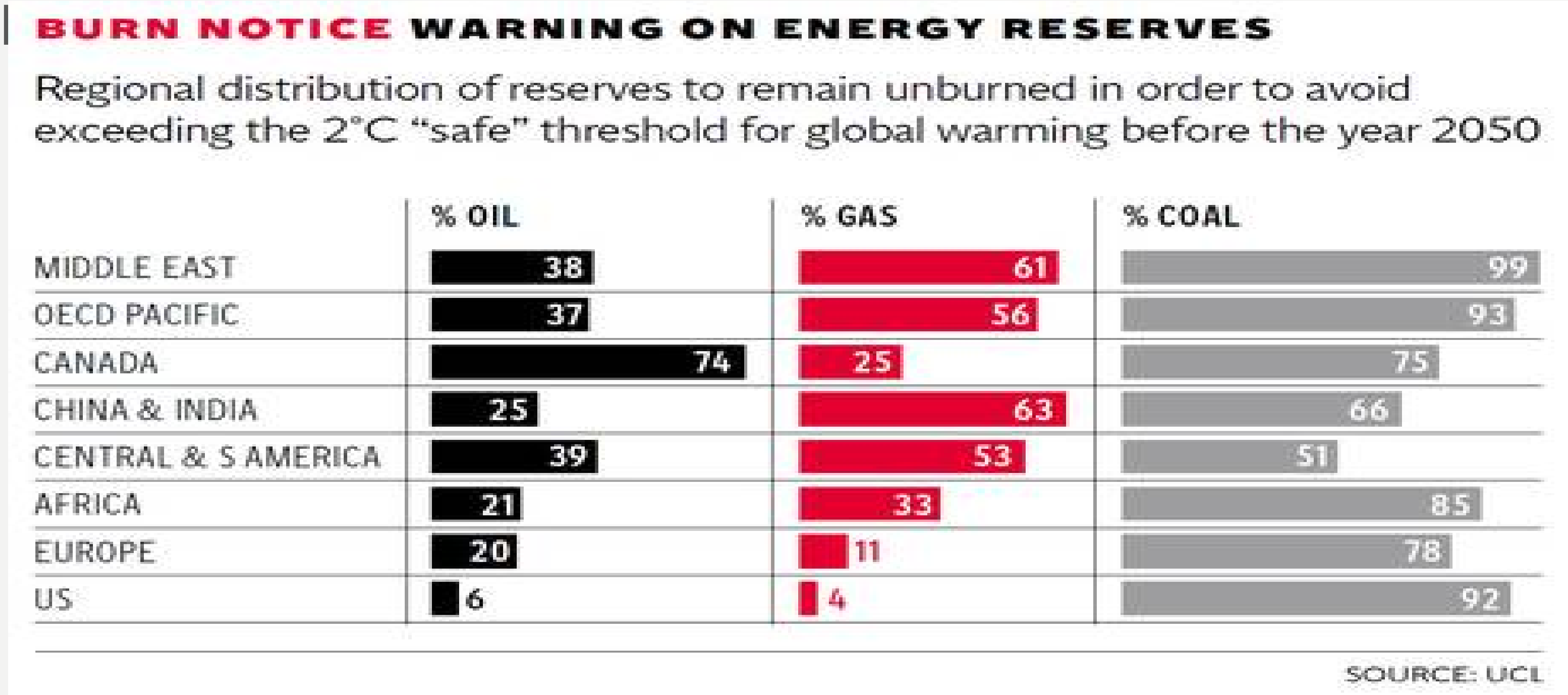
Source: van der Ploeg (2018)

WHAT GROWTH RATE FOR THE CARBON PRICE?

- Most studies use between 5 and 12%/year; UK uses 15% per year
- Much too high: procrastination of carbon pricing and inefficient
- Gollier (2019) speaks of the "The Big Green Bet":
  - Safe carbon budget is uncertain (political risk)
  - Future marginal abatement costs are uncertain
  - Future growth in emissions and consumption growth are uncertain
- $\rightarrow$ Set growth of carbon prices to safe interest rate plus *beta* times risk premium, where *beta* is correlation coefficient between log MAC and log consumption $\rightarrow$ 3.5% per year in real terms

MCGLADE AND EKINS (2015, NATURE)

- Globally keep a third of oil (all of Canada, Arctic), half of gas and 4/5 of coal (mainly China, Russia, US) reserves unburnt



4. RISK, UNCERTAINTY AND TIPPING POINTS

- “Tail risk” in economic growth prospects, global warming damages and the climate processes can be captured by skewed distributions, disaster risks and tipping point risks
- Distinguish aversion to risk (RRA) from aversion to intertemporal fluctuations (1/EIS) or intergenerational inequality (IIA = 1/EIS)
- SCC = E[PDV of future marginal damages from emitting one ton of carbon today], so need risk-adjusted discount rate
- These “tail risks” push up the carbon price significantly (e.g. Cai and Lontzek, 2019, JPE)

DISASTER RISK AND TIPPING POINTS

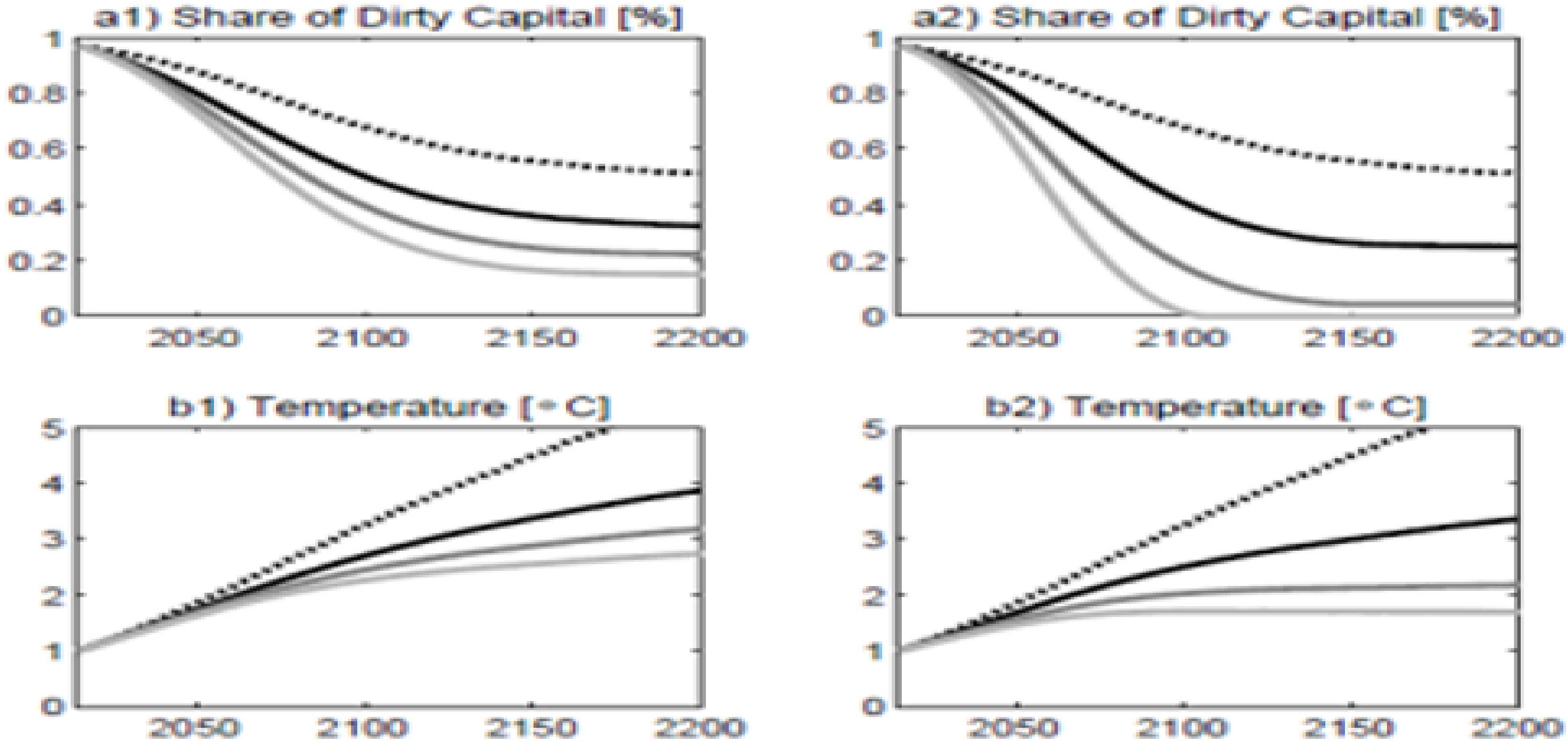
- If damage uncertainty is gradually resolved *and* preference for early resolution of uncertainty (RRA > 1/EIS), the optimal carbon price has tendency to fall (Daniel et al., PNAS, 2019)
- But swamped by rising carbon price if growth is high enough
- Recurring macro disasters push up price of carbon, especially if frequency increases with temperature
- Nine tipping points (collapse of Antarctic and Greenland Ice Sheets, melting of permafrost, reversal of Gulf Stream, etc.): this pushes up carbon price a lot (Cai and Lenton, 2019, JPE)
- Physical transition risk: tipping points more likely as planet hots up

5. DIVERSIFICATION VERSUS CLIMATE ACTION

- Negative effects of global warming on (i) production damages (Nordhaus) and (ii) frequency of climatic macro disasters (cf. Barro et al., 2019) $\rightarrow$ **two reasons to price carbon** (Hambel et al., 2020)
- Pricing carbon speeds up decarbonisation of economy; via decline of share of carbon-intensive capital and emissions, more than is needed for diversification alone
- **Diversification perspective:** diversify until there is a balance between green and dirty capital (cf. Cochrane et al., 2007)
- **Climate perspective:** run down dirty capital stock completely
- Diversification considerations may prevent driving carbon-intensive capital stock to zero if climate damages are modest (e.g. Nordhaus)

Dotted lines: hypothetical scenario with no climate damage so no climate action and full diversification (dirty capital share → 50%)

Figure 4: Effect of optimal carbon pricing on capital reallocation and temperature



Key: The dotted lines indicate a hypothetical scenario without global warming damages. The black solid lines standard calibration, whereas the grey and light grey lines show what happens if damage effects are, respectively, 2 and 3 times as high. The left panels apply if temperature affects output negatively and the right panels if temperature increase the incidence of climate-related disasters.

Source: Hambel et al. (2020)

6. POLICY TIPPING AND RISK OF STRANDED ASSETS

- Disruptions in financial markets, carbon bubbles and stranded assets due to (i) policy uncertainty, policy tipping or tipping due to technological breakthroughs or sudden preference changes and (ii) irreversible or costly-to-reallocate investments
- Transition gives rise to unburnable fossil fuel reserves (physical risks), but (i) and (ii) can also lead to sudden revaluations of financial assets and risk of stranded assets (e.g. scrap investments in coal-fired power stations, steel, cement before end of economic life) unless disorderly transition is avoided
- Important to distinguish transition risks and physical risks (Kriegler)
- Delayed climate policy is costly and leads to Green Paradox effects

RISK OF STRANDED ASSETS

- Policy tipping even worse
- 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: potential carbon bubble
- “Race to burn last ton of carbon”: 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)
- Just when need for green investments is highest, value of carbon-intensive capital and thus collateral for much needed loans to finance green investment collapses (real options argument)

7. EMPIRICAL EVIDENCE: EFFECTS OF GREEN TRANSITION ON ASSET RETURNS

- **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

- **Donadelli et al. (2020):** focuses at fossil fuel industry
  - 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 (cash/assets, debt/assets, log assets, R&D/sales)
  - Depends on awareness of climate change risks (from Google searches correlated with environmental policy stringency)

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)

- **Investors may have non-pecuniary preferences for green companies:** investors accept 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**: 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)

8. MACRO-FINANCIAL POLICY FOR GREEN TRANSITION

- Should Taylor rule respond to global warming when output falls and competitiveness deteriorates? Not if there is divine coincidence?
- Negative effects of carbon pricing on output are curbed if the carbon tax or permit revenue is used to cut the labour income or consumption tax rather than rebating it via transfers, especially if there is a lot of wage and price sluggishness (Jaimes, 2020)
- Procyclical carbon tax cuts risk premia, boosts welfare (Benmir et al., 2020)

- Liquidity costs of banks increase with carbon intensity of their portfolio, banks favour low-carbon assets, so easier to finance green transition: emissions-based interest rates (Böser and Senni, 2020)
- Sectoral time-varying macroprudential weights on loans for green investments and a carbon tax makes both green and carbon-intensive asset purchases more attractive (Benmir and Roman, 2020)
- Easing reserve ratios for low-carbon lending (Campiglio, 2016)
- Use central bank collateral to cut emissions (McConnell et al., 2020)

9. DISORDERLY TRANSITION & PRUDENTIAL POLICIES

- **Network approach:** Acemoglu et al. (Ectra). Acemoglu, Ozdaglar, Tahbaz-Salehi (AER, 2015) et al., Barabasi → multiple equilibria!
- **Financial contagion:** with small negative shocks, a dense financial network with more diversified pattern of interbank liabilities enhances financial stability but with larger negative shocks propagation of shocks and fragile financial system - same factors lead to resilience under certain conditions but to systemic risk under other conditions
- Endogenous networks with number of new nodes linked to most connected existing nodes and with links made endogenous (e.g. due to defaults)
- Need empirics on *structure* of networks (star, sparse, dense, directed or not), default risks and contagion: network structure matters!
- Climate (like monetary) policy might make networks denser, so strong climate policies will have larger effects than small climate policies

- Fossil fuel industry may ignite financial crisis if green transition is disorderly and market panic ensues
- High leverage and borrowers' balance sheets expose favour fire sales to deleverage; lending channels might dry up, thus causing a general credit crunch and money hoarding; runs on financial institutions –not only on banks; strong network effects and large shadow banking sector
- Riding a carbon bubble is rational for all for as long these self-reinforcing linkages push prices up and liquidity is forthcoming (cf. "musical chairs" analogy of J.M. Keynes)
- Financial regulators are aware of these risks so there is strong case for climate stress testing the financial system

GREEN TRANSITION RISK

- Carbon-intensive firms face risk of default if there is a sudden future stepping up of climate policy … or breakthrough in green technology
- Default with limited liability, average risk pricing of deposits and excessive leverage implies need for capital requirements (Mendecino et al., 2020)
- Is there a case for differential capital requirements and prudential policies for green and carbon-intensive assets?
- Carbon risk premium found by Bolton & Kacperzyk (2020ab) 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)
- Firms more subject to low-carbon transition risk have to pay higher

10. CONCLUSIONS

- Determine safe carbon budget and commit to steadily growing carbon price at say 3.5% per year
- Take account of climatic and economic risks
- Carbon price should start of high enough (avoid Green Paradox effects)
- Case for independent emissions authority
- Use revenue to compensate low incomes and firms that are most at risk of carbon-intensive imports from abroad if border tax adjustments are infeasible (avoid leakage)
- Use debt or transfers to generation intergenerational win-win
- May need carbon-intensive sector for a while to finance green transition and for diversification reasons but carbon-intensive capital must fall

- Need complementary macro policies: green quantitative easing, more stringent prudential policies for carbon-intensive companies
- Need public funds to finance low-carbon transition
- Investors already increasingly demand higher returns from carbon-intensive companies to be compensated for transition risk
- Carbon-intensive firms already need to pay higher interest on their loans
- Avoid disorderly green transition: policy uncertainty and policy tipping and abrupt breakthroughs in technology or changes in preferences can lead to abrupt changes in stock market valuation of both carbon-intensive and green companies and the risk of stranded assets
- Transition risks can be amplified in networks through defaults and contagion, especially when balance sheets are not well diversified
- Need climate stress tests and roll out initiatives taken by NGFS and others

THANK YOU