Climate change and the macro-economy

A central bank perspective

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Introduction

Motivation

Why is climate change important for central banks?

- Individual and systemic financial risk
- Monetary policy: inflation, potential growth and spillovers

See e.g. Lane (2017), Cœuré (2018), Debelle (2019)

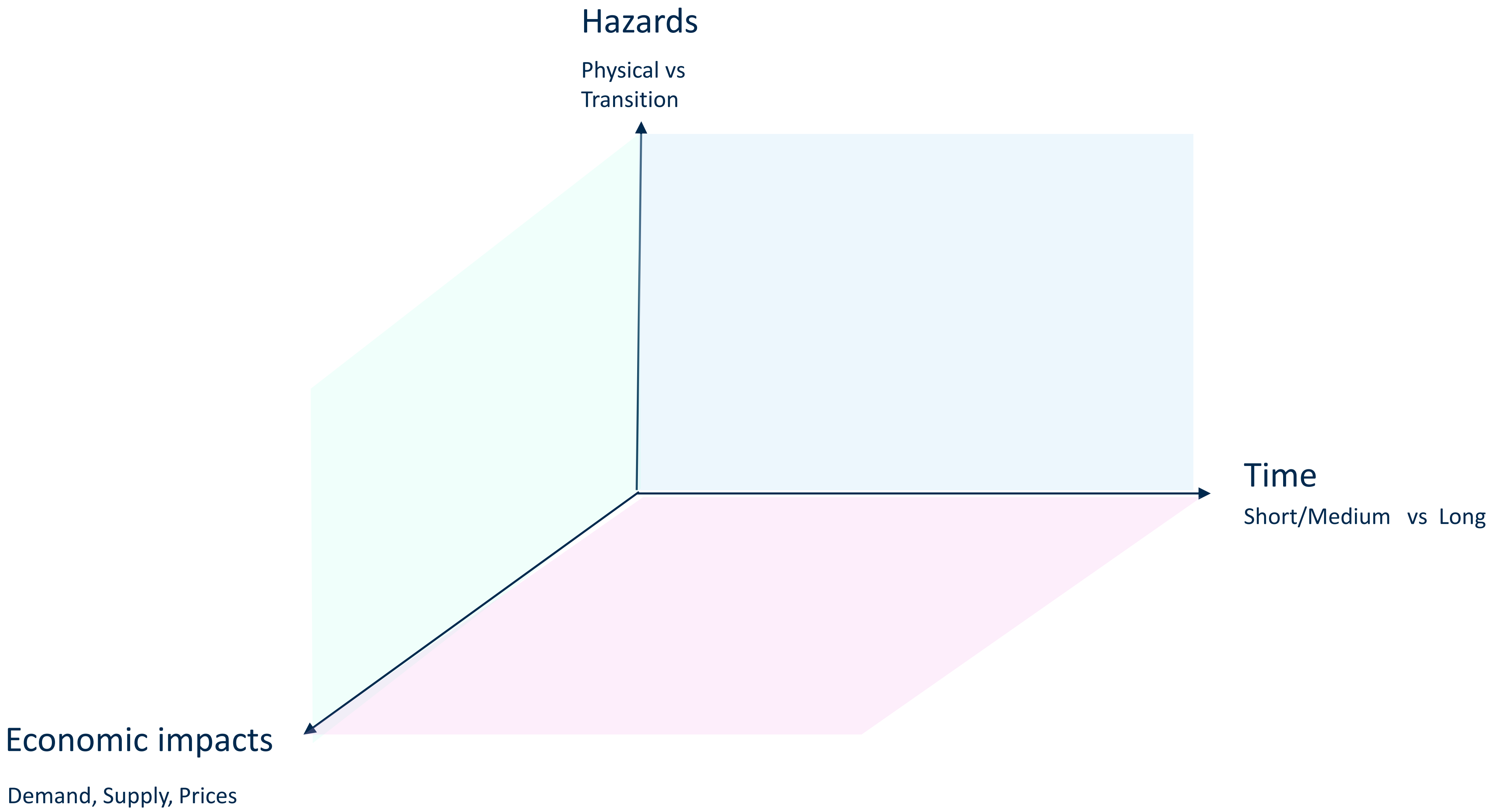
Climate – related risks: definition

Climate related risk =

Probability of climate hazard

× Consequences

Climate – related economic risks: problem dimensions



Plan

1. Physical hazards

2. Transition hazards

3. Economic impacts

4. Financial stability impacts

Summary: Economic impacts of climate change and timing

Type of risk		Economic outcome	Timing of effects
Physical risks from:	Extreme climate events	Unanticipated shocks to components of demand and supply	Short to medium run
	Global warming	Impact on potential productive capacity and economic growth	Medium to long run
Transition risks		Demand/supply shocks or economic growth effects	Short to medium run

References

Batten, Sowerbutts and Tanaka (2016) "Let's talk about the weather: the impact of climate change on central banks" Bank of England SWP 603

Batten (2018) "Climate change and the macro-economy: a critical review", Bank of England SWP 706

Batten, Sowerbutts and Tanaka (2018), "Climate change: What implications for central banks and financial regulators?" in *Stranded Assets and the Environment,* Routledge

Batten, Sowerbutts and Tanaka (2020) "Climate change: Macroeconomic impact and implications for monetary policy", in *Ecological, Societal, and Technological Risks and the Financial Sector*; Springer

See also: BoE Climate change web page

1. Physical risks

Definition of physical hazards

Physical hazards

Raising average temperatures and consequences, e.g. sea level rise, increase in rainfalls

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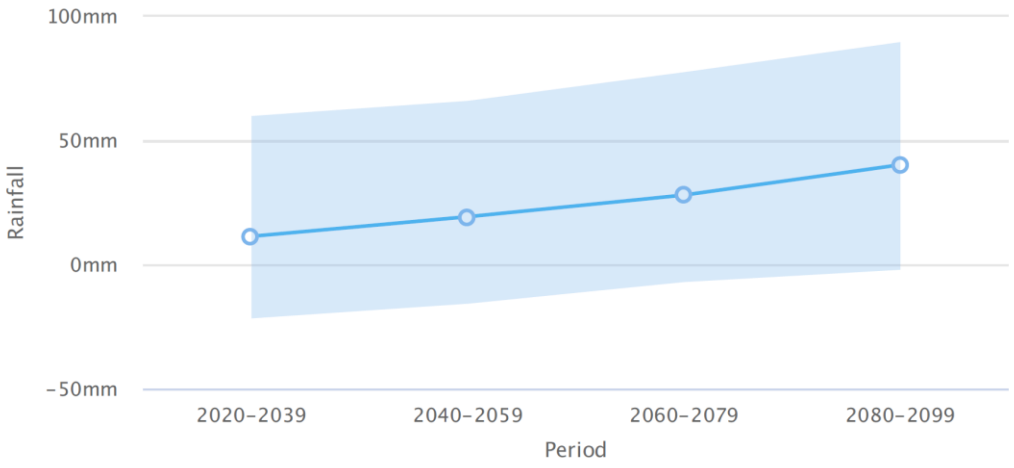
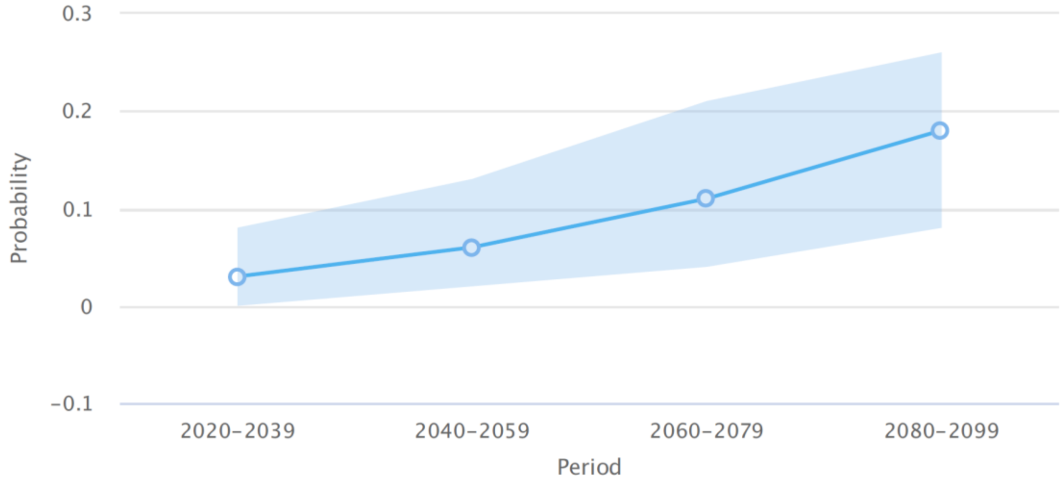
Increase in the frequency and severity of climate related events: e.g. floods

Physical hazards - probability

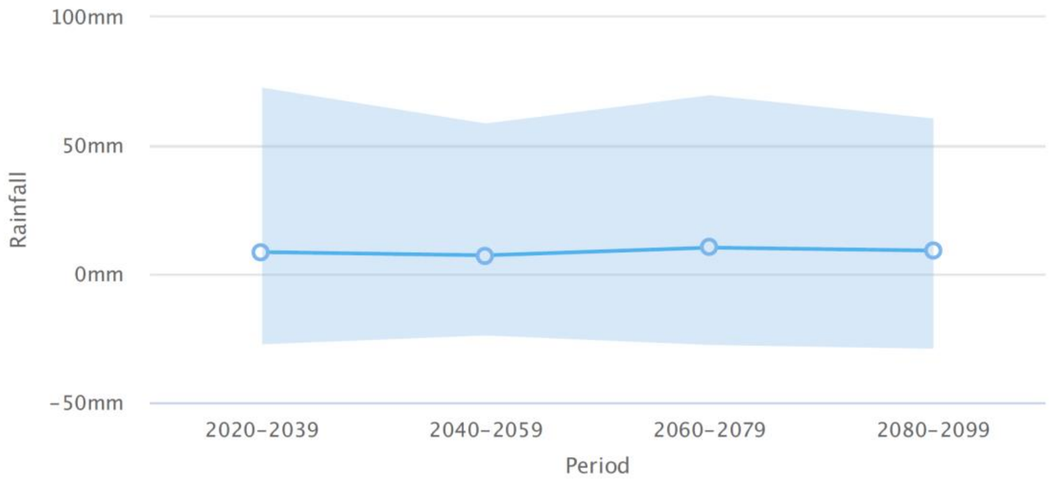
Rainfalls | **Heatwaves**

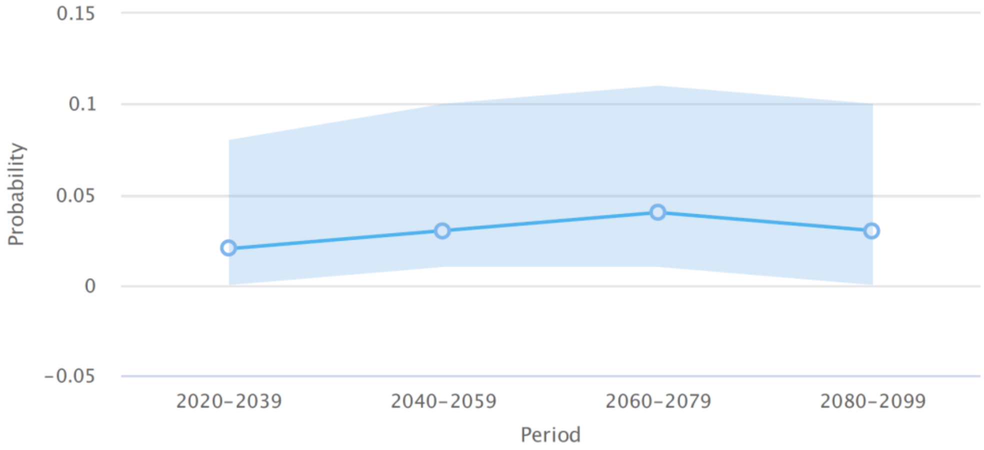
High warming scenario (RCP 8.5)





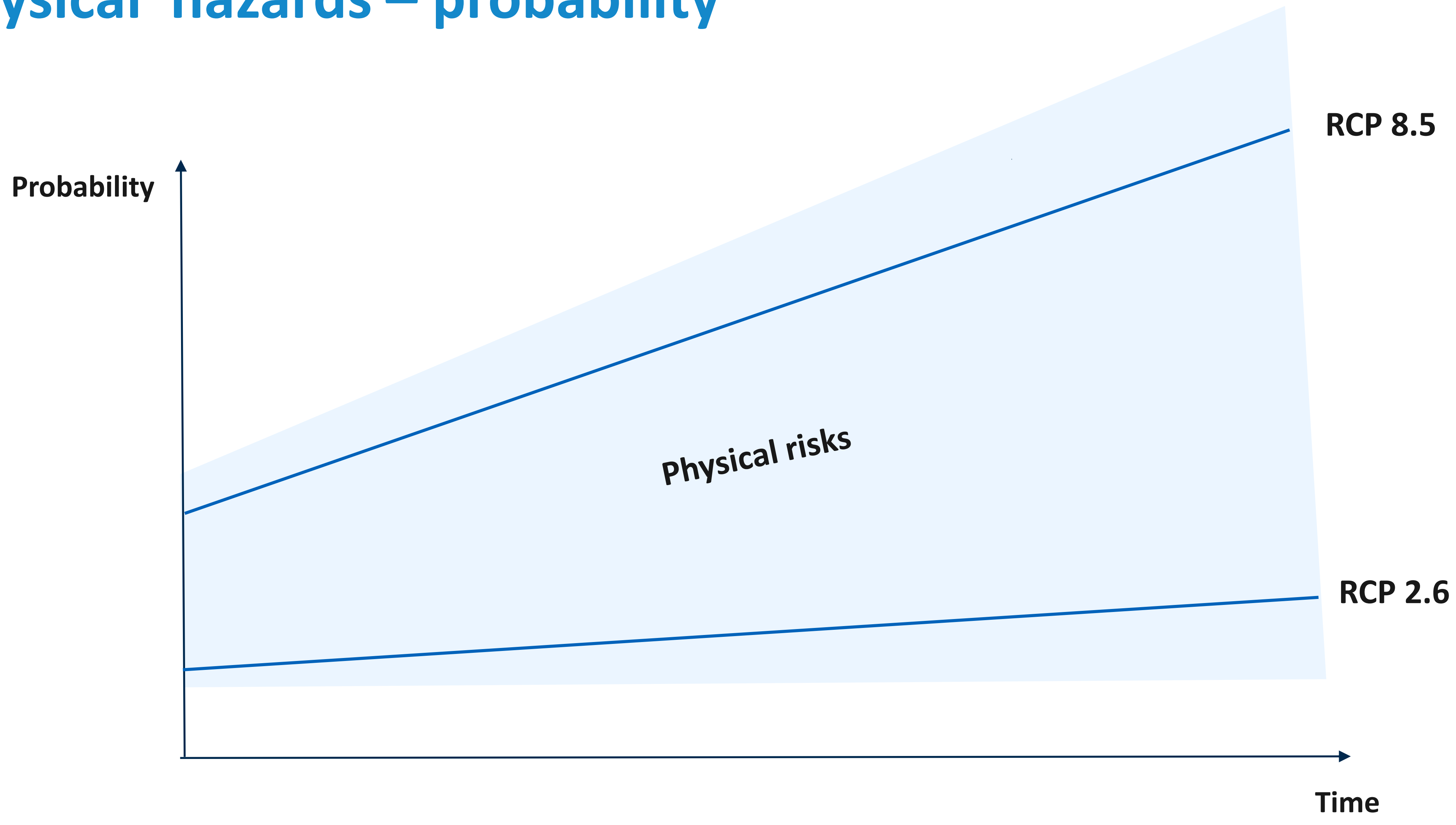
Low warming scenario (RCP 2.6)



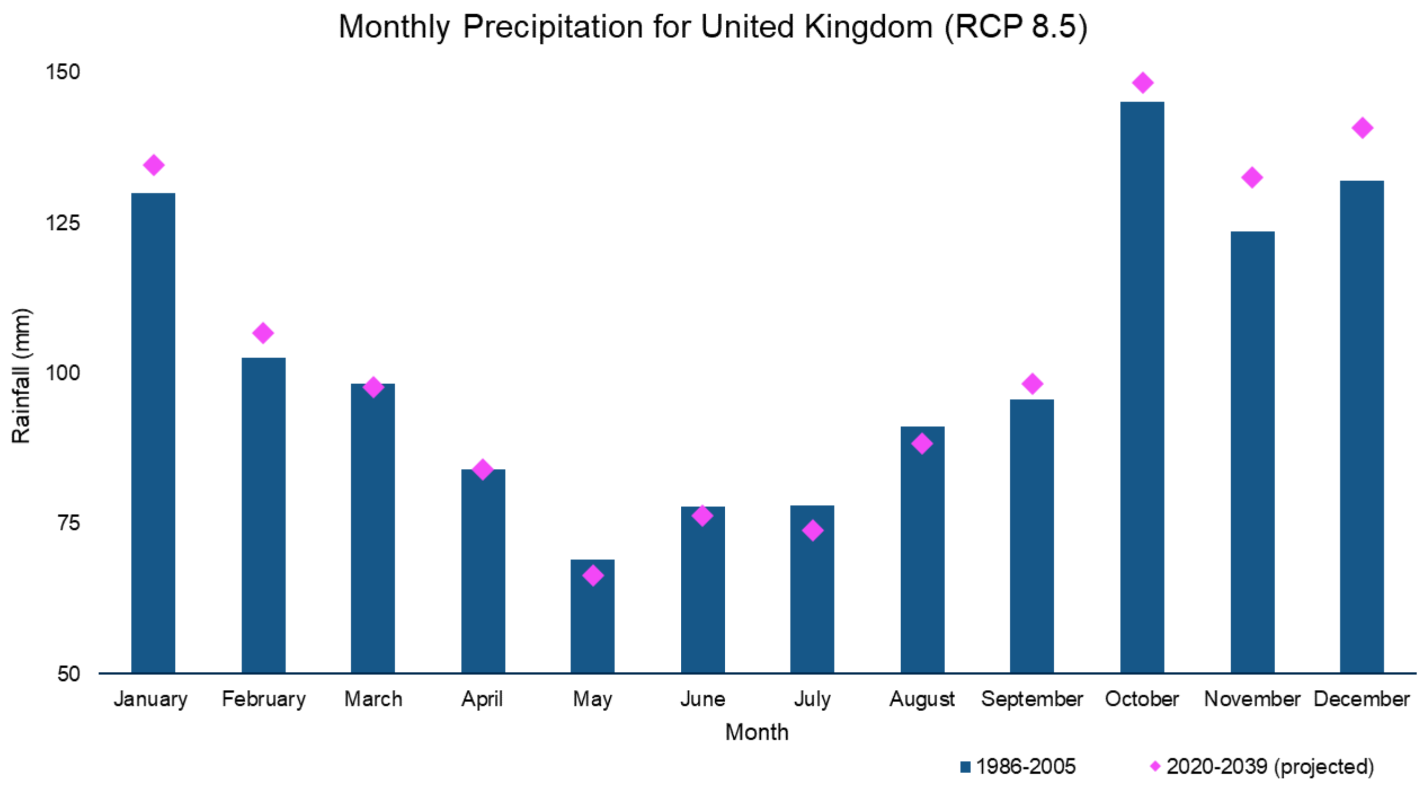


Note: Projected changes in UK annual values relative to 1986-2005 average. Source: World Bank

Physical hazards – probability

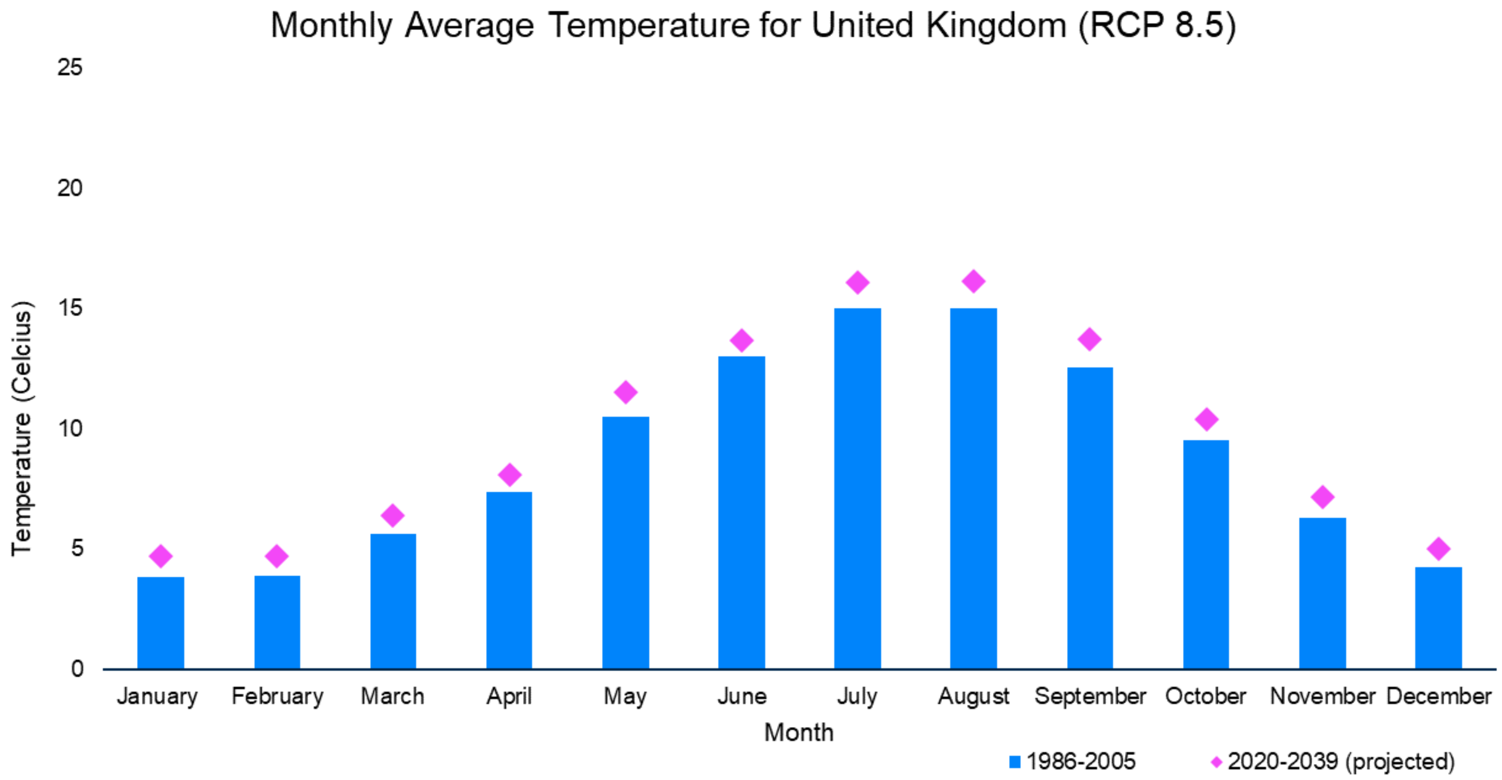


Physical hazards over the short to medium run: precipitations



- Projections for precipitations in winter months over this decade and the next already higher than the reference period (1986-2005).

Physical hazards over the short to medium run: temperatures



- Temperatures also projected to be higher on average in every month of the year.
- Heatwaves projected to be 3% more likely on average over this decade and the next.

2. Transition risks

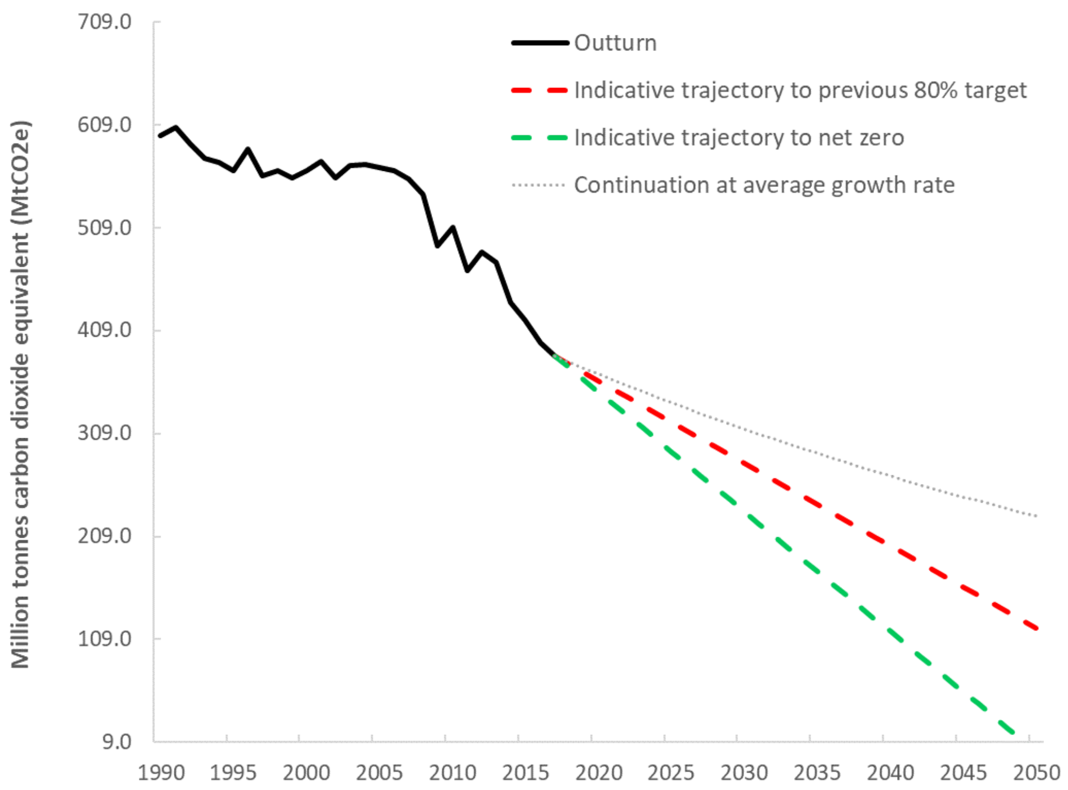
Types of climate – related hazard

Transition hazards

- Climate policy
- Technology
- Expectations

Transition hazards: policy

UK CO_2 emissions and target



Source: BEIS, CCC (2019)

Taxonomy of climate policy instruments

Type	Instrument	Example
Command and control instruments (regulation)	Input controls over quantity and or mix of inputs	Ban on coal
	Technology controls	Mandatory CO_2 capture and storage methods on a power plant Standards to increase the energy efficiency of automobiles, appliances, and buildings
	Performance standards	Limit emissions to a certain number of grams of CO_2 per kilowatt-hour of electricity generated
Economic incentive (market based) instruments	Emission charges/taxes	Carbon taxes
	Emission abatement subsidies	Subsidies for R&D in clean energy generation Subsidies for adoption of clean energy/products/technologies Reduction of direct and indirect subsidies for fossil fuel use
	Marketable (transferable) emission permits	Emission trading schemes
Institutional approaches to facilitate the internalisation of externalities	Facilitation of bargaining	Emissions disclosure
	Development of social responsibility	Energy conservation media campaigns
	Voluntary agreements	Legally binding agreements for industrial energy efficiency improvement

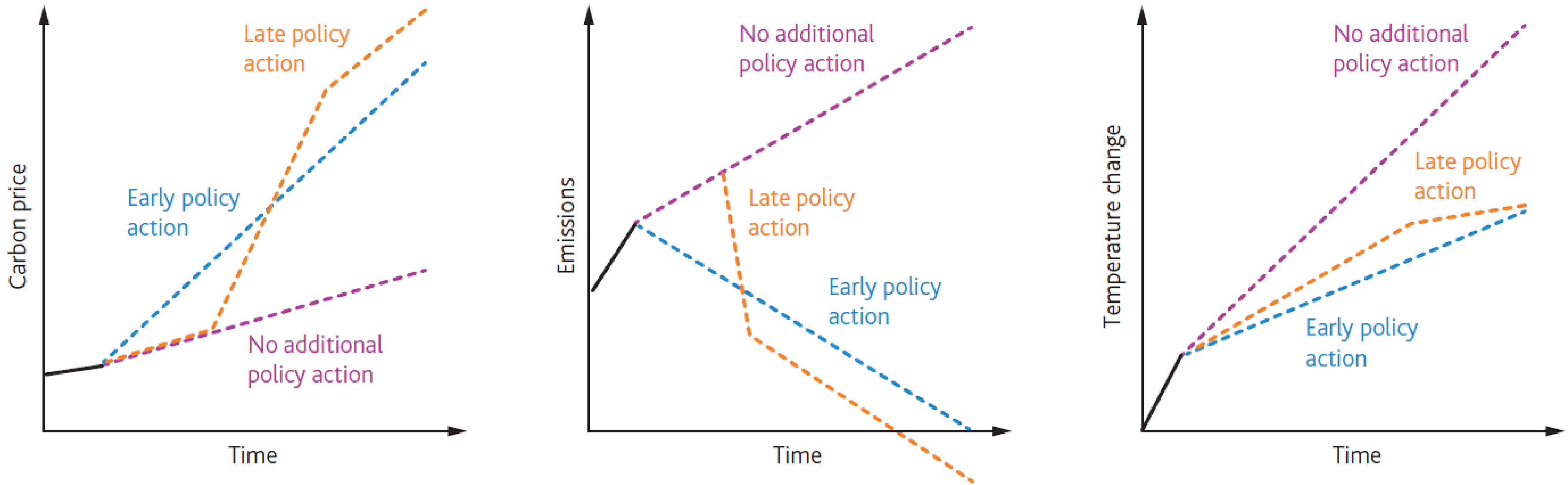
Based on Perman et al. (2011); informed by Gupta et al. (2007), Duval (2008) and Whitley (2012)

Reaching net zero emissions in the UK

1. **Core scenario:**
   - sectors: buildings, industry, power, transport, aviation and shipping, agriculture and land use, waste, F-gases, and greenhouse gas removals (GGRs)
   - achieves 80% target
   - broadly reflects the Government's ***current level of ambition*** (but not necessarily policy commitment or action)
2. **Further ambition scenario:**
   - societal changes are also required
   - achieves 96% GHG reduction
   - higher cost, lower technology readiness
3. **Speculative scenario:**
   - changes required alongside 1. and 2. to reach net-zero target
   - significant additional societal and behavioural changes, more ambitions GGRs and new carbon-neutral fuels
   - currently very low levels of technology readiness, very high costs, or significant barriers to public acceptability

(Source: CCC 2019)

Transition risks: illustrative pathways

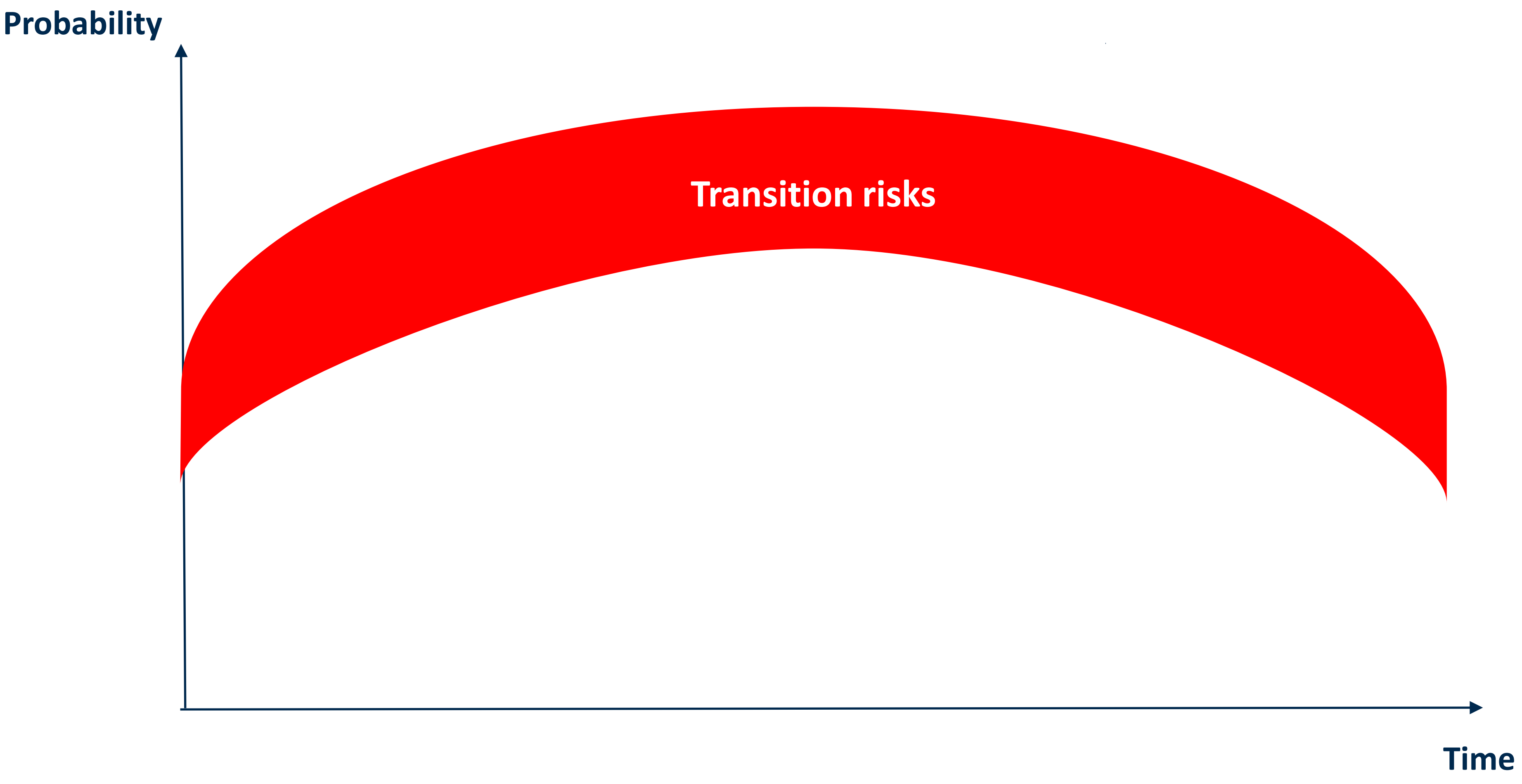


Source: BoE (2019)

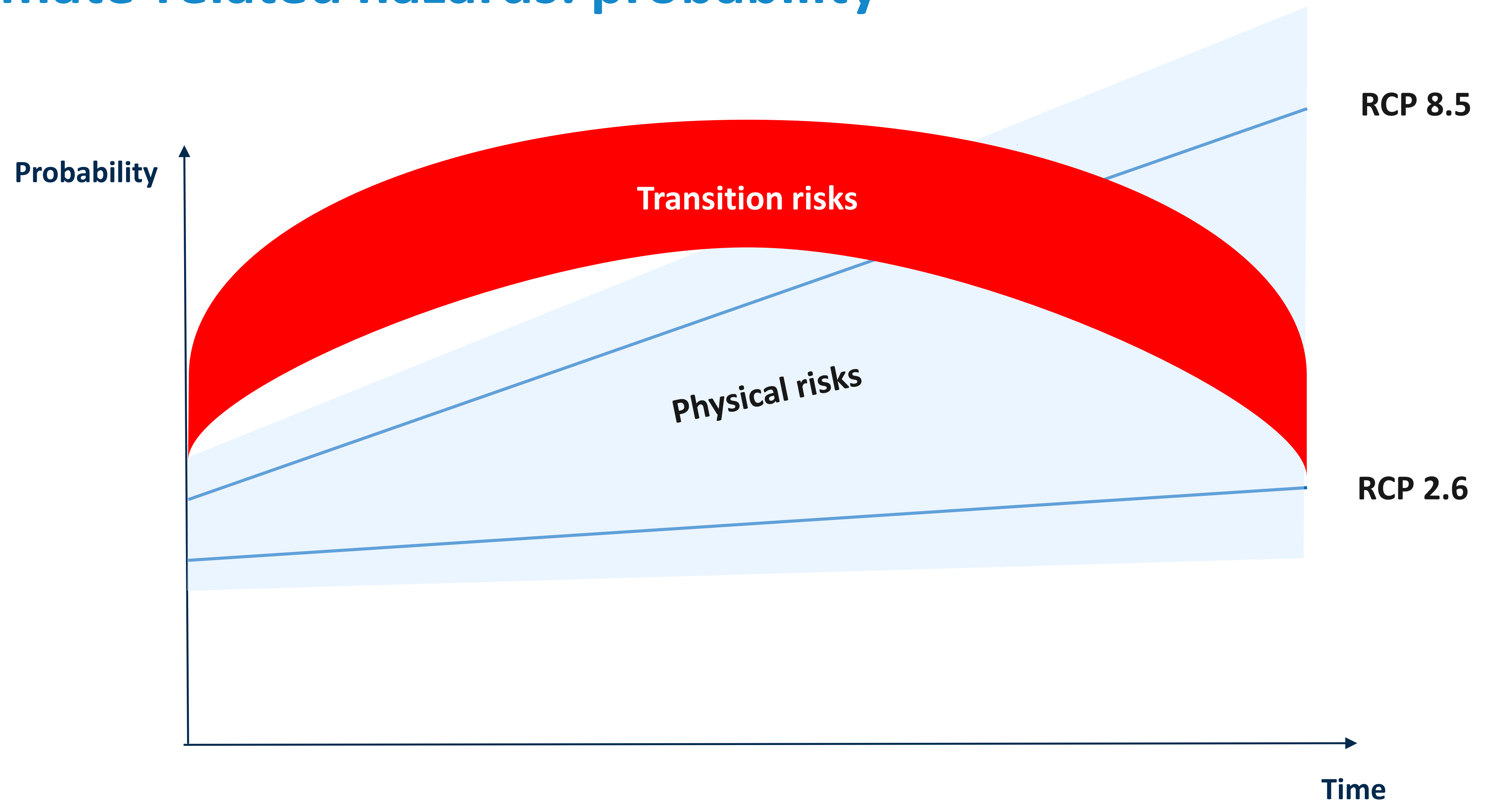
Other transition hazards: technology and expectations

- Technology:
  - Technological spillovers: upward risk to growth, particularly with ambitious scenario
- Expectations:
  - Consumers: boycotts/social unrest
  - Investors: fossil fuel divestment
- Most likely a combination of the three elements will drive the transition.

Transition hazards – probability



Climate-related hazards: probability



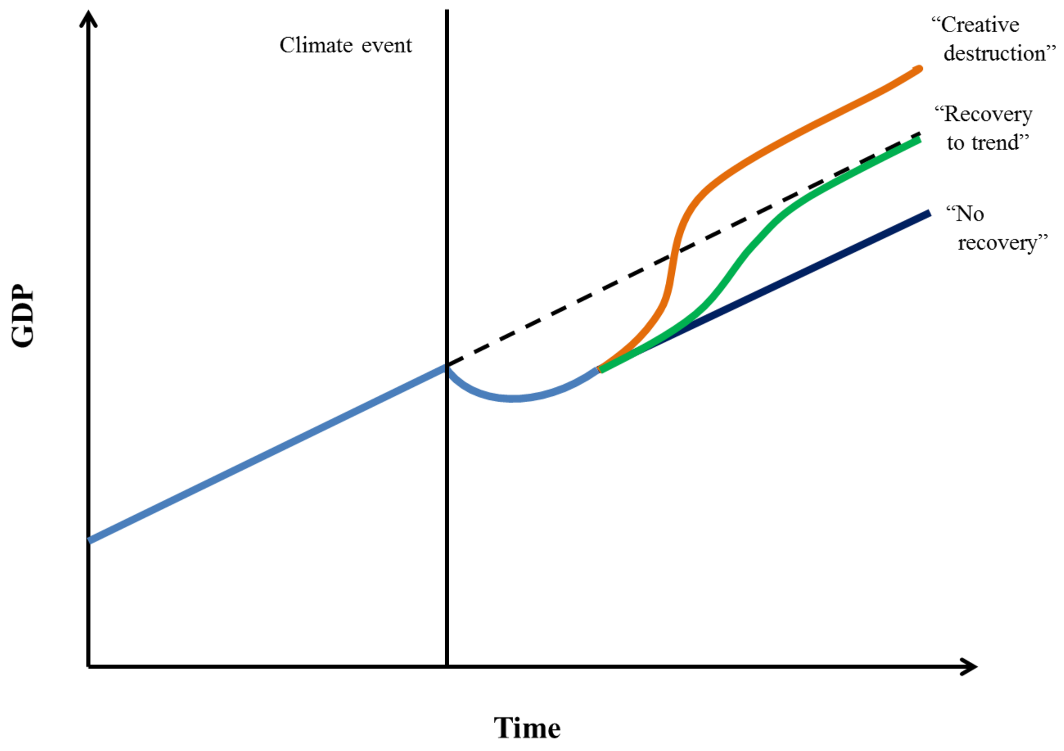
3. Climate change economic impacts

Economic impacts: physical hazards

Channel		Physical risks
Demand	Investment	Reduction in business investment due to the uncertainty/volatility of extreme climate events
	Consumption	Wealth effects through loss or depreciation of housing stock
	Trade	Disruption to import/export flows due to natural disasters
	Government expenditure	Loss to structures/infrastructure
Supply	Labour supply	Loss of hours worked due to extreme weather events
	Energy, food and other inputs	Food, energy and other input shortages
	Physical and infrastructure capital stock	Damage due to climate events. Diversion of resources from productive investment to adaptation
	Technology	Diversion of resources from innovation to adaptation

- Longer term effects include the effects of climate-induced migration, conflicts, and increased morbidity and mortality

Empirical evidence: impact of natural disasters on GDP



Source: modified version of Figure 1 in Hsiang and Jina (2014)

Empirical evidence:

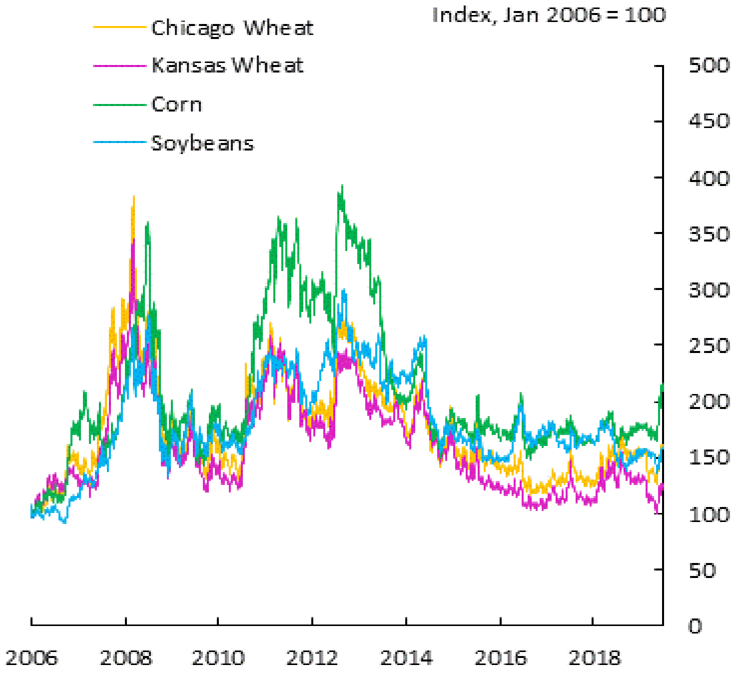
- Toya and Skidmore (2007)
- Cavallo and Noy (2010)
- Hsiang and Jina (2014)
- Felbermayr and Gröschl (2013, 2014)

Examples of monetary policy reaction:

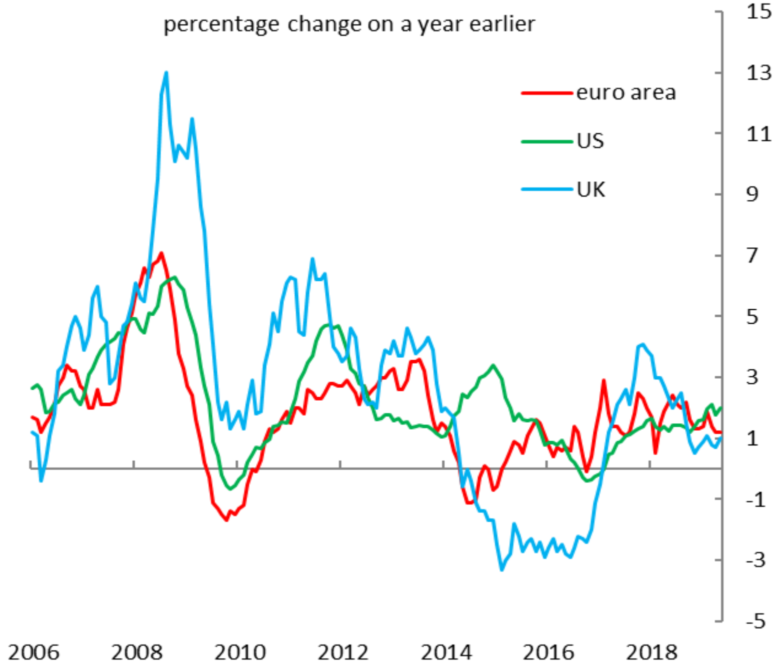
- Hurricane Katrina (2005)
- Great East Japan Earthquake (2011)
- Flooding in Thailand (2011)

Inflation effects of natural disasters

Selected food commodity prices, 2006-2019



Food price inflation, 2006-2019



Recent evidence:

- Heinen et al. (2016)
- Parker (2018)
- Peersman (2018)

Source: Thomson Reuters Datastream

Channels

Channel		Empirical evidence
Demand	Consumption	• Beltrán et al (2016): immediately after an inland flooding event, house prices are 24.9% lower. But no statistically different effect after 4-5 years, apart from lower-priced properties.
	Trade	• El Hadri et al. (2017): a severe windstorm curbs agricultural export by 7% in small countries; a flood, is estimated to reduce export flows of a poor country by around 1.78%.
Supply	Labour supply	• Martin et al (2011): 2003 heatwave resulted in loss in manufacturing output of £400-500m (2003 prices). • Crichton (2006): UK SME's lost over 50 working days on average as a result of flooding.
	Energy, food and other inputs	• NERA (2012): The financial cost of water usage restrictions in London has been assessed to be in the range of £236m - £329m per day.
	Infrastructure capital	• UK Environment Agency: flooding in the summer of 2007 caused damages of about £674 million to important national infrastructure and the operation of essential services.

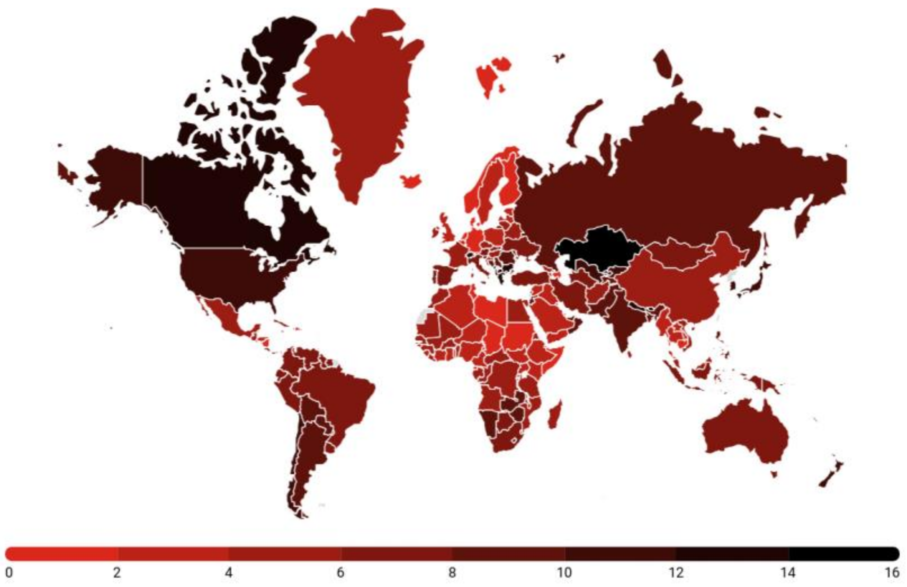
Impact of temperature rise on GDP

- **Dell et al. (2012):** find that a 1°C rise in temperature in a given year reduced economic growth in that year by 1.1 percentage points (in poor countries only)

- **Burke et al. (2015):** model the growth rate of GDP per capita as a nonlinear function of temperature and find that the growth rate of output per capita peaks at an annual average temperature of 13°Celsius and declines strongly at higher temperatures

- **Khan et al. (2019):** derive a climate change-growth specification from a theoretical growth model, control for the endogeneity of temperatures, and show that a temperature increase (decrease) above (below) its historical norm by 0.01°C annually, leads to a reduction in GDP growth by 0.0543 percentage points per year

Percentage loss in GDP per capita by 2100 in absence of climate policy (RCP 8.5 scenario)



Source: Khan et al. 2019

Economic impacts: transition hazards

Channel		Transition risks
Demand	Investment	'Crowding out' from climate policies
	Consumption	'Crowding out' from climate policies
	Trade	Distortions from asymmetric climate policies
	Government expenditure	Inefficient climate policy
Supply	Labour supply	Lack of skills; labour misallocation
	Energy, food and other inputs	Risks to energy supply
	Capital stock	Capital misallocation; premature K depreciation and scrapping
	Technology	Uncertainty about the rate of innovation and adoption of clean energy technologies

Empirical evidence: transition risks

- Evidence on impact of existing climate policies (Martin et al. 2014a,b, Calel and Dechezleprêtre 2016, Dechezleprêtre and Sato 2017)

- Macroeconomic impact of stranded fossil fuel assets (Mercure et al. 2018)

- Different economic models that assess GDP impacts of decarbonisation based on different assumptions provide different results (OECD, 2017, IPCC, 2014)

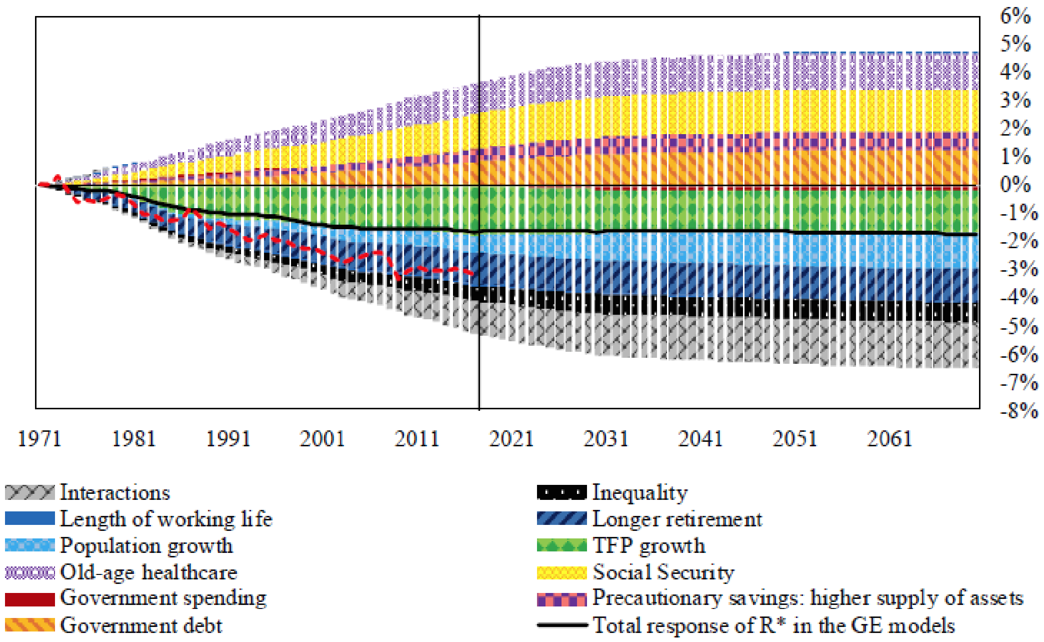
- ‘Resource cost’ estimates of different policies (CCC, 2019) tend to include only static effects

Climate change impact on the natural rate of interest

- The natural rate of interest can be defined as the rate that is consistent with stable inflation when the economy is growing at its trend
- Neoclassical (Ramsey) growth model formulation of the natural rate:

$$r^* = \frac{1}{\sigma} g_c + \theta$$

- Theoretical determinants of r^*:
  - rate of growth of technology g
  - rate of growth of population n
  - intertemporal elasticity of substitution σ
  - rate of time preference θ.



Changes in the equilibrium real interest rate as a result of policy, demographic and technological shifts (source: Rachel and Summers 2019)

Climate change impact on the natural rate of interest (cont.)

Component	Example of climate change impact
Rate of growth of technology g	Climate policy might increase g through promoting green energy technologies; other climate change-driven innovation (e.g. for adaptation) might increase g.
Rate of growth of population n	Climate change could reduce life expectancy (extreme heath). Demographic trends can also affect intertemporal preferences
Fiscal policy	Climate change could increase government debt (higher mitigation and adaptation investment, higher expenditure e.g. health and other costs of natural disasters), and thus increase r*
Income inequality	Climate change is likely to increase income inequality and thus reduce r*

Relevance for monetary policy

- Physical risks:
  - Can have non-negligible economic impacts over forecast horizon
  - Likely to increase volatility of output and inflation

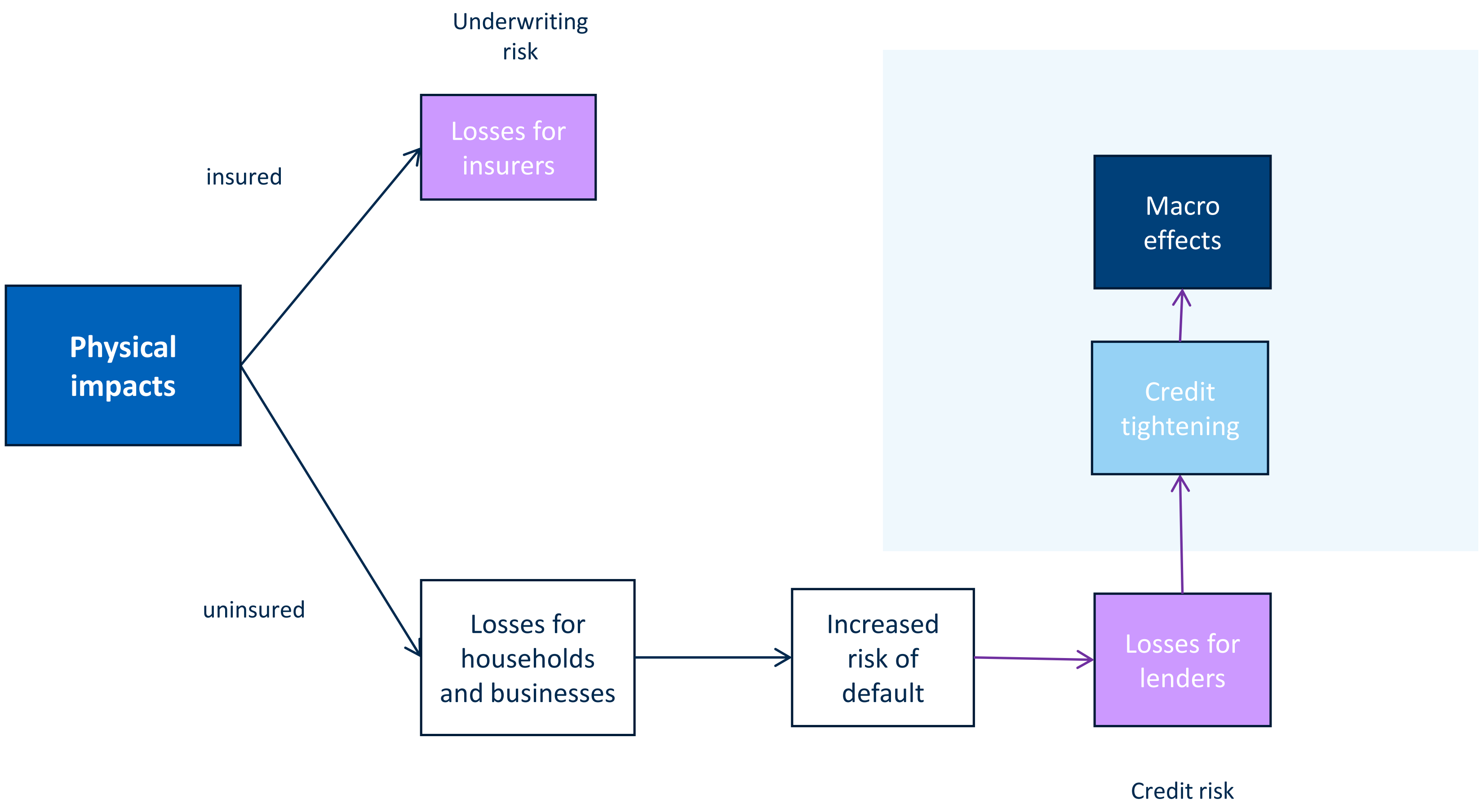
- Transition risks:
  - Carbon pricing will have an impact on inflation
  - Risks to growth:
    - Upward risks if significant technological spillovers
    - Downward risks if the transition leads to resource misallocation or to a significant policy drag on growth

Implications for the analytical framework of central banks

- Assessing weather impacts (Gourio 2015; Bloesch and Gourio 2015)
- Deviations from seasonal norm (Boldin and Wright 2015)
- Including climate in DSGE modelling (Keen and Pakko 2011)
- Incorporate evidence on economic effects of climate policy (Martin et al. 2014)
- New modelling tools? (e.g. NiGem)

4. Climate change financial stability impacts

Financial stability impacts: Physical hazards



Stranded assets

- Absent a significant break-through in climate technology, remaining within the 2°C limit on climate change will necessitate a substantial reduction in carbon emissions.
- Estimates include up to 80% of coal, 50% of oil and 30% of gas international reserves could become unusable, i.e. ‘unburnable’ or ‘stranded’

Are these risk being incorporated into asset prices?

Need to carry out risk assessment for:

- Equity markets stability
- Credit markets stability
- Risk of contagion or market volatility

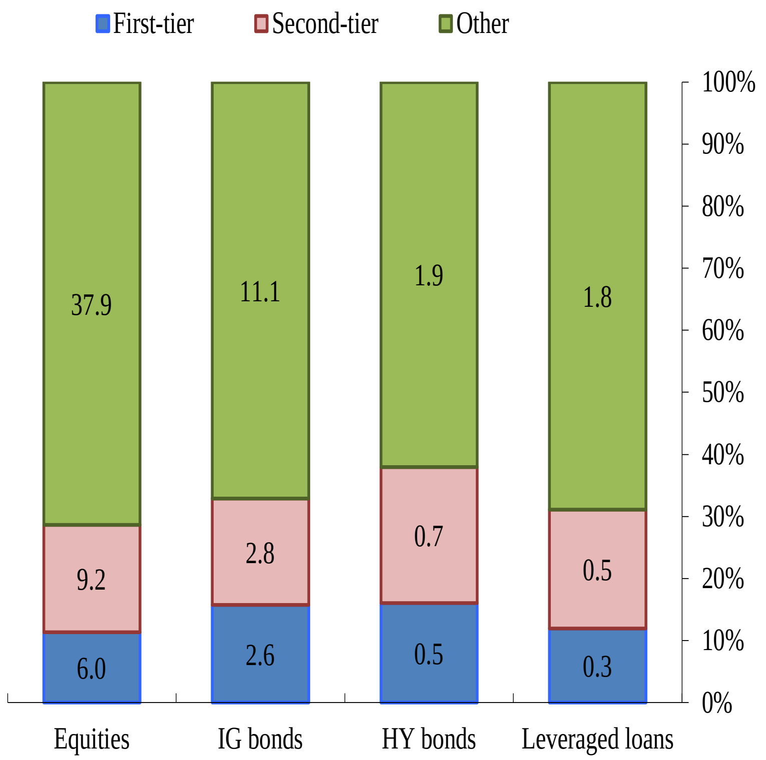
Risk assessment: equity and credit markets

Identify types of industries affected to different degrees by a limit on carbon emission:

- ‘first-tier’ companies: impacted directly by limits on their ability to produce fossil fuels These include: **global coal/oil/gas companies and energy utilities**;

- ‘second-tier’ companies: wider group of energy-intensive companies that will be affected indirectly via an increase in energy costs. These include **chemicals, forestry and paper, metal mining, construction and industrial production**.

The stranding of carbon assets could also have an impact on the ***credit markets***, if it were to impact the perceived or realised ability of firms to service their debt.



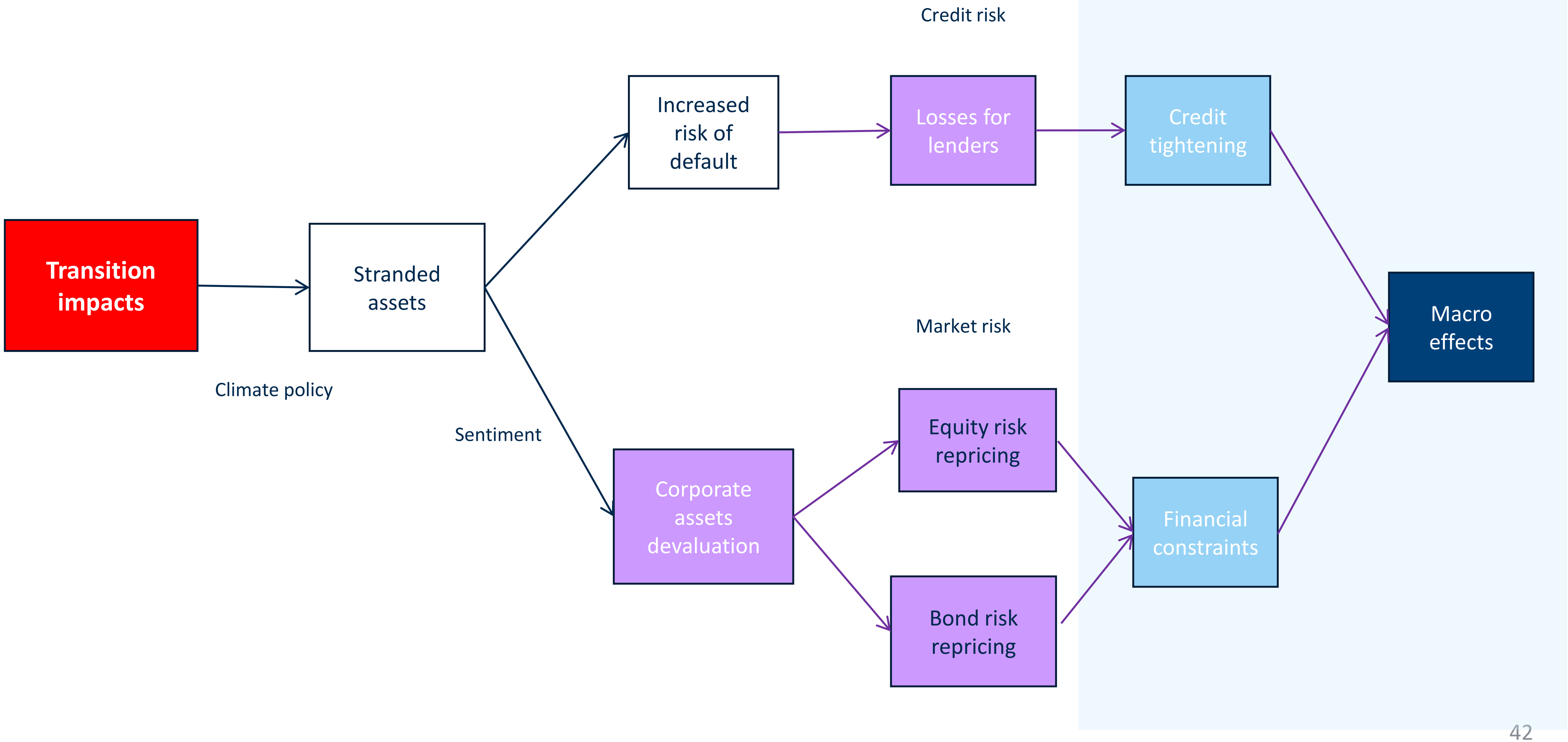
Risk assessment: contagion

- Financial markets could also play a role in amplifying the effects of carbon-asset stranding, particularly if such a transition were to take place rapidly and unexpectedly.

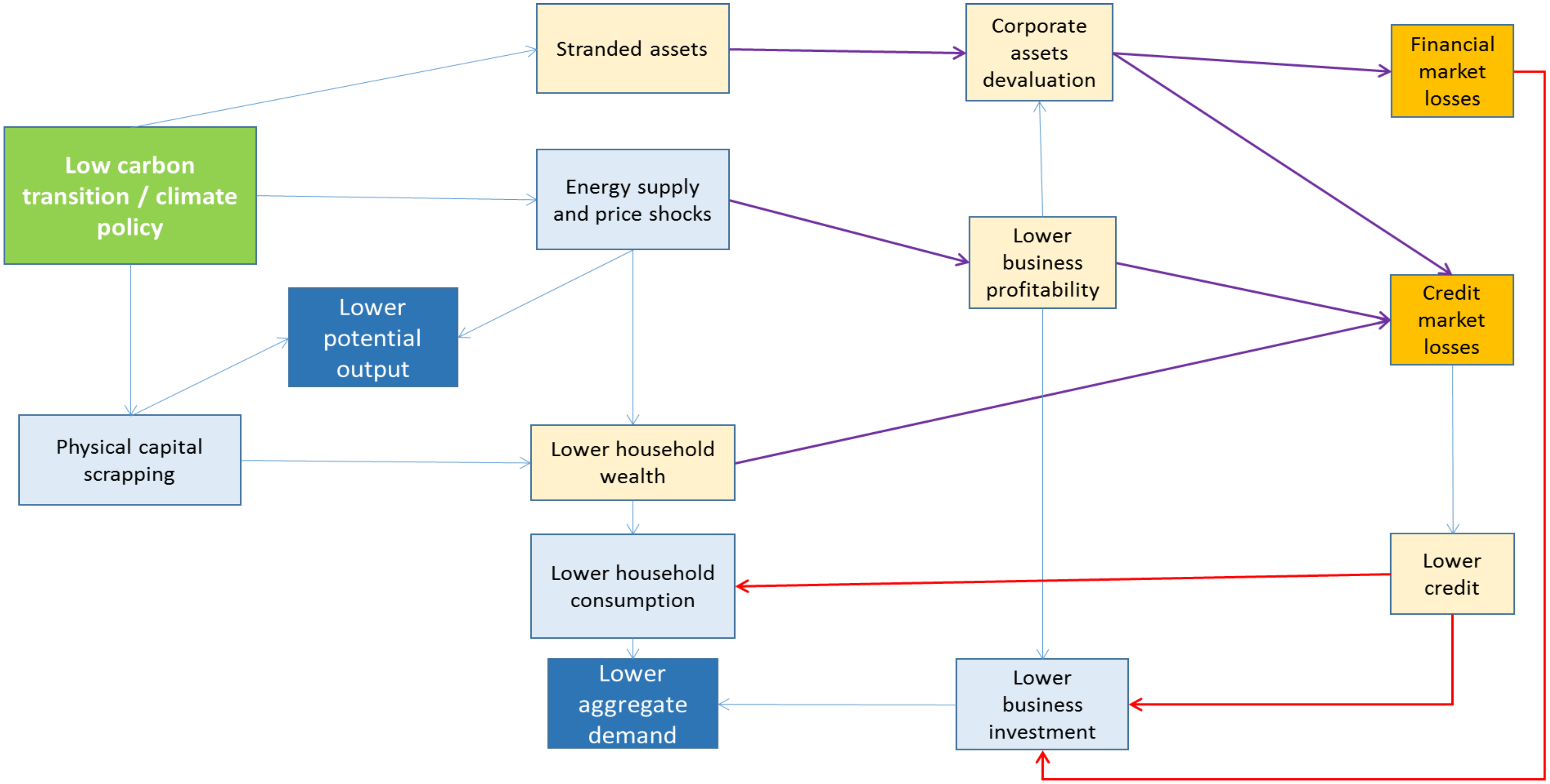
- Corporate bond markets ***contagion*** might happen if investors cannot sell the energy-related debt due to its increased illiquidity and sell other corporate debt instead to limit their credit exposures.

- An instant correction of equity prices could cause a spike in ***market volatility***, which could prompt various market participants (e.g. hedge funds) to exercise ‘stop-loss’ trades, exacerbating the downward price moves and causing an increase in financial markets risk premia more broadly.

Financial impacts: Transition hazards



Macro-financial spillovers from transition risks



Any questions?

Thank you